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THE DISTRIBUTION OF ANIMALS AFTER THE DELUGE[1]

By the Reverend WILLIAM KIRBY, M.A., F.R.S.

HAVING considered the first creation of the animal kingdom, and the larger features of its history to the time of the Deluge, bringing us to that era when our globe had assumed its present general characters, and its population was in those circumstances that led to their present habits and stations: the next subject to be discussed is their geographical and local distribution.

What had taken place in this respect before the Deluge we have no means of ascertaining. That the original temperature of the earth was once more equal than it is now, seems to be the general opinion of men of science, however they may differ as to its cause. If this was the case, as it probably was, any individual species might have been located in any country, north or south, and suffer no inconvenience from unaccustomed heat or cold, so as to interfere with its complete naturalization: the only other requisite would be a kind of food suited to its nature; and it is singular and worthy of particular attention, that a large proportion of the plants, as well as animals, that are found in a fossil state in our northern latitudes are of a tropical type or character.

After their creation, and perhaps the expulsion of the first pair from Paradise, we may suppose that the various animals of the ante-diluvian world were guided to those regions in which it was the will of Providence to place them, by a divine impulse upon them, which caused them to move in the right direction. Probably before the Deluge took place, the world was everywhere peopled with

[1] First part of Chapter II of "The History, Habits and Instincts of Animals," being part of the Bridgewater Treatises, established by the will of the Earl of Bridgewater with a bequest of eight thousand pounds placed at the disposal of the president of the Royal Society for works "On the Power, Wisdom and Goodness of God, as manifested in the Creation." Published by Carey, Lea and Blanchard, Philadelphia, 1836.

animals: and perhaps, as Professor Buckland has suggested, the sudden change of temperature that destroyed the northern animals might be one of the predisposing causes of that event.

Under the present head, the geographical distribution of our post-diluvian races of animals, the first thing to be considered is the means by which, after quitting the ark, they were conveyed to the other parts of the globe. The disembarkation of the venerable patriarch and his family, followed by all the animals preserved with him in the ark, a scene of universal jubilee to man and beast, such as the world till that day had never witnessed, took place on Mount Ararat: the stream of interpreters, ancient and modern, place this mountain in Armenia; but Shuckford, after Sir Walter Raleigh, seems to think that Ararat was further to the east, and belonged to the great range anciently called Caucasus and Imaus, which terminates in the Himmaleh mountains to the north of India. This opinion seems to receive some confirmation from Scripture, for it is said, *"As they journeyed from the east, they found a plain in the land of Shinar."* Now the Armenian Ararat is to the *north* of Babylonia, whereas the Indian is to the *east*. Again, as the ark rested upon Ararat more than *ten* weeks before the tops of the mountains were seen, it seems to follow that it must have been a much higher mountain than the generality of those of the old world. The modern Ararat (Agri-Dagh) is not *three* miles above the level of the sea, whereas the highest peak of the Himmaleh range, Dhawalagiri, is *five,* and the highest mountain in the known world; so that the tops of a great number of mountains would have appeared previously had the ark rested upon the former Ararat, but not so if upon the latter. The traditions also of various nations, given by Shuckford, add strength to this opinion. In addition to these, the following lines, quoted in a late article on Sanscrit poetry, in the Quarterly Review, show what was the creed in India on this subject:

In the whole world of creation——
None were seen but these seven sages, Menu and the fish;
Years on years, and still unwearied, drew that fish the bark along,
Till at length it came where reared Himavan—its loftiest peak;
There at length they came, and, smiling, thus the fish addressed the sage:—
Bind thou now thy stately vessel to the peak of Himavan—
At the fishes' mandate, quickly to the peak of Himavan:
Bound the sage his bark, and even to this day that loftiest peak
Bears the name of Naubandhana.

Both these opinions have their difficulties, which I shall not further discuss, but leave the decision of the question to persons better qualified than myself to direct the public judgment: I shall only observe, that perhaps the Indian station was more central and convenient for the ready dispersion of men and animals than the Armenian

one. Every naturalist is aware that there are many animals that, in a wild state, are to be found only in particular countries and climates. Thus the Monkey and Parrot tribes usually inhabit a warm climate, the Bears and Gulls with many other Sea-birds, for the most part a cold one. The Kangaroo and Emu are only found in New Holland; the Lama in Peru; the Hippopotamus and Ostrich in Africa. Now we may ask, how were all these local animals conveyed from the place of disembarkation to the countries and climates that they severally inhabit? In considering this question, we must never lose sight of Him, according to whose will, and by whose Almighty guidance, they were all led to the stations he had appointed for them, and with reference to which he had organized and formed them. Whatever second causes he might commission to effect this purpose, they were fully instructed and empowered by him to accomplish the work intrusted to them. I do not mean here to infringe the rule, *Nec Deus intersit nisi dignus vindice nodus.* Where the faculties, senses, and wants of an animal were sufficient for its guidance, there was no need for Divine interposition, but where these are insufficient guides, the animal must attain its destined station under some other influence.

What brought the various animals to the ark previously to the deluge? Doubtless a *divine* impulse upon them, similar to that which caused the milch-kine to carry the ark of the covenant to Bethshemesh, with the offerings of the lords of the Philistines. Noah, though he probably selected the clean animals, at least those that were domesticated, could have little or no influence over the wild ones to compel them to congregate by pairs, at the time fixed upon for their entry into the ark. So in the dispersion of animals, wherever man went he took his flocks and herds, and domestic poultry, and those in his employment for other purposes, with him: but the wild ones were left to follow as they would, or rather as God directed.

Every one who looks at a map of the world, on Mercator's projection, can easily conceive how the animal population of the greatest part of the old world made their way into the different countries of which it consists, but when he looks at America and New Holland, he feels himself unable satisfactorily to explain the migration of animals thither, especially those that can live only in a warm climate, at least as far as regards the former. How, he might ask, did the Sloths, the Anteaters, and the Armadillos get to South America? If the climate of Behrings Straits, after the deluge, was as cold as it is at this day, they could never have made their way thither, and in those latitudes the temperature of which was adapted to their organization the vast Pacific presents an insuperable barrier.

The same question may be asked with respect to the indigenous animals of New Holland; the Kangaroo, the Cola, the Ornithorhynchus, the Emu, and several others that are found in no other country; how did they, leaving the continent altogether, convey themselves to this their appointed abode? It is true difficulty is not so great in this last case, on account of the numerous islands interposed between Malacca, Cochin-China, etc., and the North Coast of New Holland, but then it is unaccountable, if the transit of these animals was gradually effected by natural causes, and following that of mankind from island to island, till they reached the country to which their range is now limited, that they should have left no remains of their race in the countries and islands which they must have traversed in their route; and those that would have accompanied man would be a different tribe of animals, more fitted to minister to his wants, so that with respect to these the difficulty still remains—they could not have reached the country unless under the guidance of Providence, and the same power that accomplished their removal to that appointed for their residence, prevented their leaving any of their race in the regions through which they passed.

There is only one supposition that will enable us to account for the transport of these animals in a natural way, which is this, that immediately subsequent to the deluge, America and New Holland, and the various other islands that are inhabited by peculiar animals, were once connected with Asia and Africa, by the intervention of lands that have since been submerged. Plato, in his Timæus, relates a tradition concerning an island called Atlantis, which he describes as bigger than Asia and Africa, situated before the pillars of Hercules, which after an earthquake was swallowed up by the sea. According to his statement, this account was given by the Egyptian priests at Sais, to Solon, the Athenian legislator. Catcott, in his history of the deluge, seems to give some credit to this tradition, and supposes that Phaleg took his name, not from the confusion of tongues at Babel, and the subsequent division of the earth amongst the families of the three sons of Noah, but from its division occasioned by the subsidence of this great island, by which the occidental were separated from the oriental countries of the globe. Philo Judæus speaks of this catastrophe in terms that imply he gave credit to it, as does also Tertullian; but it appears to me to rest on too uncertain a base, and to be too much mixed with evident fable and allegory, to claim full credit as a real fact in the history of our globe. Still that many violent convulsions have taken place since the deluge is generally supposed. Our own island is thought once to have formed part of the continent, Sicily to have been united to Italy, with many other instances mentioned

by Pliny. It is equally probable that the islands of the Indian Archipelago were at one time joined to that part of Asia. Whether such disruptions from the continents were simultaneous, or took place at different periods, is uncertain; but if such an event as the submersion of the vast island of Plato did really happen, it surely would affect the whole terraqueous globe, produce convulsions far and wide, and cause various disruptions in its crust, and elevations in other parts from the bed of the ocean. It throws some weight into this scale, that thus a way would be open, though certainly a circuitous one, for the migration of those animals to America, that are found in no other part of the world, and, supposing Asia to have been disrupted from it at Behrings Straits, could scarcely have ascended to so high a latitude, in search of their destined home.

Malte-Brun, in his geography, after proving that the animals in question could have passed neither from Africa nor Asia, observes—"Nothing, therefore, remains, but the accommodating resource of a tremendous convulsion of nature, with a vast tract of country swallowed up by the waves, which formerly united America with the temperate regions of the old world. Such conjectures as these, however, being devoid of all historical support, do not merit a moment's consideration; consequently we can not refrain from admitting, that the animals of America originated on the very soil, which, to this present day, they still inhabit."

That it might have been the will of the Creator to people the country in question by the immediate production of a new race of animals, suited to its climate and circumstances, I will not deny, but I would only ask, is it consistent with what occurred at the deluge? Surely the task of Noah would have been much less difficult and laborious, had it been merely necessary for him to construct a vessel fitted for the reception of himself and family, and of food for their sustenance during their confinement; and a new race of animals had been created, adapted to the then state of the earth and mankind. But such was not the will of God, and, doubtless, for wise reasons. He would neither create a new race of men, nor a new race of animals, when the world might be repeopled by those already in being. This would not have harmonized with the ordinary proceedings of his providence. Whoever examines the animals of North America, will find a vast number that correspond with European species, distinguished only by characters that mark varieties. On the Rocky Mountains, and in the country westward of that range, Asiatic types are discoverable, both in the vegetable and animal kingdoms. Several animals, likewise, of the southern part of that Continent belong to old world genera, and also species. I have received from Valparaiso a beetle, common in Britain, and Molina mentions several other European genera, as natives of

Chili; so part of the animal population of the New World appears to have been derived from Europe and Asia; and if so, there is a door open, through which Providence might also have conducted those North American animals that are found in no other country.

But besides the probable, or possible, modes by which the transit of animals to their respective settlements might have been accomplished, Mr. Lyell, in the second volume of his Principles of Geology, has suggested one which might, amongst others, have been employed for this purpose.

"Captain W. H. Smyth informs me," says he, "that, when cruising in the Cornwallis, amidst the Philippine Islands, he has more than once seen, after those dreadful hurricanes called typhoons, floating islands of (*matted*) wood, with trees growing upon them; and that ships have sometimes been in imminent peril, in consequence of mistaking them for terra firma." Mr. Lyell conjectures, not improbably, that by means of such an insular raft, or wandering Delos,—"if the surface of the deep be calm, and the rafts carried along by a current, or wafted by a slight breath of air fanning the foliage of the green trees, it may arrive, after a passage of several weeks, at the bay of an island, into which its plants and animals may be poured out as from an ark; and thus a colony of several hundred new species may at once be naturalized." Thus he accounts for the peopling of the volcanic and coral islands in the Pacific.

It must be borne in mind that nothing really happens by chance, or is the result of an accidental concourse of fortuitous events: second causes are always under the direction of the *first,* who ordereth all things according to the good pleasure of his will; and therefore the elevation of a new island from the bosom of the deep, whether immediately produced by volcanic agency, or by an earthquake, or built by Zoophytes, still may be denominated *his* work; so likewise the same Almighty Guardian of the universe, whose name is Jehovah of Hosts, directs all the actions and motions of the hosts that he hath created, to the full accomplishment of every purpose that, in his wisdom, he hath formed. When we are assured that the hairs of our head are all numbered, and that not a sparrow falleth without our Heavenly Father, we are instructed to look beyond second causes for the direction and management of events that appear at first sight the most trivial, but which, in their immediate or remote consequences, may be productive of effects that are important to be attended to and provided for.

We know that when animals of any kind exceed certain limits, though beneficial in the ordinary exercise of their instincts, they become noxious. God alone knows when they approach these limits; it is he, therefore, that employs man or other animals to destroy a certain number of them, that they may bear a due proportion to

other beings on which they act; or if he wills to punish mankind, he suffers their numbers to increase so as to answer this intention. But to all his hosts, he says, "*Thus far shalt thou go and no further.*" Therefore, when the ocean, or fires below its bed, or other causes elevate islands above its surface, it is he that conducts to them the population he intends should occupy them.

The islands of Bourbon and Mauritius both appear to be of volcanic origin: amongst their aboriginal animal inhabitants was a most extraordinary gallinaceous bird, called the Dodo; this bird, like the ostrich and cassowary, had only rudiments of wings, and of course was unable to fly; being unfit for food, though of the gallinaceous order, and a very ugly and disgusting object, it soon became extinct in those islands, and the only remains of it are a leg and foot at the British Museum, and a skeleton of the head in the Ashmolean Museum at Oxford. It has been contended that this bird, having never been discovered elsewhere, was peculiar to these islands, but there are reasons for believing that it was not the only species of its genus, for Latham has included in it two others, both stated to have been found in African islands. This affords a strong presumption that the headquarters of the genus are on the continent of Africa, and that these three species have been conveyed to the islands they are stated to have inhabited by some accidental cause. By the direction of Providence, a floating island, like that seen by Captain Smyth, might be the means of conveying this and their other inhabitants to them.

I think, therefore, that there is no necessity to have recourse to a new and more recent creation, to account for the introduction of its peculiar animals into any given country.

The fact itself, that almost every country has its peculiar animals, affords a proof of design, and of the adaptation of means to an end, demonstrating the intervention and guidance of an invisible Being, of irresistible power, to whose will all things yield obedience, and whose wisdom and goodness are conspicuous in all the arrangements he has made. Wherever we see a peculiar class of animals we usually see peculiar circumstances which require their presence. Thus the elephant and rhinoceros, the lion and the tiger, are found only in warm climates, where a rapid vegetation, and infinite hosts of animals, seem to require the efforts of such gigantic and ferocious devourers to keep them in check: but on this subject I shall have occasion to enlarge hereafter.

There is another point of view, illustrative of the Divine attributes in this partial location of various animals. If every region, or nation, contained within its limits the entire circle that constitutes the animal kingdom, and the remark may be extended to every natural object, how weak and trifling would be the incitement for

man to visit his fellowman. Were the productions of every country the same, there would be little or no temptation for commercial speculation, therefore the merchant would stay at home; the animal, and plants, and minerals would be the same, therefore the naturalist would stay at home; the astronomer indeed, and geographer, and the student of his own species, might be tempted sometimes to roam, but the ocean would be truly *dissociable,* and those ties that now connect the different nations of the globe would, for the most part, be broken. They are now linked to each other, in a bond of amity, by the intercourse which their mutual wants produce, and the body geographical, if I may use such a metaphor, as well as the body natural, is so tempered, and so furnished in every part, that constant supplies of things, necessary or desirable, are uninterruptedly circulating, by certain channels, through the whole system; and thus keep up a kind of systole and diastole, which diffuses everywhere a healthy temperament, and is universally beneficial. It is, moreover, calculated to generate those kindly feelings which ought to reciprocate between beings inhabiting the same globe, and sprung from the same original father. And the cultivation of these feelings of mutual good will was, no doubt, the principal object of the Deity in the distribution of various gifts to various countries, endowing some with one peculiar production and some with another: so that one might not say to another, "*I have no need of you.*"

Herein is the Divine wisdom and goodness most conspicuous. Had chance, or nature, as some love to speak, directed the distribution of animals, and they were abandoned to themselves and to the circumstances in which they found themselves in their original station, without any superintending power to guide them, they would not so invariably have fixed themselves in the climates and regions for which they were evidently intended. Their migrations, under their own sole guidance, would have depended, for their direction, upon the season of the year, at which the desire seized them to change their quarters: in the height of summer, the tropical animals might have taken a direction further removed from the tropics; and, in winter, those of colder climates might have journeyed towards instead of from them. Besides, taking into consideration other motives, from casual circumstances, that might have induced different individuals belonging to the same climates to pursue different routes, they might be misled by cupidity, or dislike, or fear. On no other principle, can we explain the adaptation of their organization to the state and productions of the country in which we find them—I speak of local species—but that of a Supreme Power, who formed and furnished the country, organized them for it, and guided them into it.

THE STATE OF SCIENCE IN 1924[1]

THE ORIGIN OF MAN

By ARTHUR SMITH WOODWARD, LL.D., F.R.S.

Relationship between Man and the Apes

There are many structures in the human body not specially adapted for present use, which can only be satisfactorily explained by supposing that man is descended from animals which once lived in trees. The structures are so numerous and so striking that a few years ago Professor F. Wood Jones wrote a whole book about them entitled "Arboreal Man." It has indeed been said that if there had been no trees in the world, there could never have been man in his present form.

If this inference be correct, we naturally look to the apes and monkeys of the present day as affording the best idea of the ancestors which we suppose to have existed. We thus, on strictly scientific grounds, recognize a relationship between man and apes, which has long been fancifully imagined by speculators who have merely been familiar with their external appearance. Science, however, would not admit that any of the existing apes are the unaltered descendants of those which, ages ago, gave rise to man. Just as man has gradually become a perfect biped, adapted for an easy upright gait when walking on the ground, so the apes have acquired an increasingly effective adaptation for swinging about in trees. Just as man has lost the power of his jaws in proportion as his hands have become more mobile, so the apes have acquired more powerful jaws and teeth both to increase the efficiency of their feeding and to improve their means of offense and defense. Science, indeed, points to a remote common ancestor of man and apes, which might by changes in two divergent directions become either one or the other. This ancestor, of course, would be popularly described as an ape if it happened to be still living, but it would be very different from any modern ape. It would be less forbidding in aspect—more like the comparatively fascinating baby of the modern ape.

Unfortunately, of animals which formerly lived in the world, we scarcely ever find more than the hard parts. Of ancestral apes and man we can only expect to discover the bones and teeth. The nature of the soft parts, therefore, can only be inferred from the shape and

[1] Prepared for the Handbook to the Exhibit of Pure Science, arranged by the Royal Society for the British Empire Exhibition.

markings of the bones. In fact, in searching for ancestors the skeleton alone concerns us.

Points of Contrast

The skeleton in both apes and man happens to be very characteristic and it is easy to distinguish the former from the latter. First, in all the apes the brain-case is comparatively small, and the face very large, often prominent; in modern man the brain-case is large and beautifully domed, while the face is comparatively small. Secondly, most of the apes have relatively large and prominent bony brow-ridges when they are full-grown; modern man lacks such brow-ridges. Thirdly, in all the apes the bony chin is receding, and the canine (or corner) teeth are relatively large and interlocking, as in a dog or cat; in modern man the bony chin is a little prominent at its lower edge, and the canine teeth are neither large nor interlocking—they are in an even series with the rest of the teeth. Fourthly, in all the apes the backbone is nearly straight—it is so even in the gibbons, which can run swiftly on their hind limbs; in modern man the backbone has a beautiful S-shaped curvature to produce the elasticity which is needed for a comfortable upright gait. Fifthly, in all existing apes, at least, the arms are relatively much longer than in man, and the great toe is as well adapted for grasping as the thumb. Sixthly, in the apes, as a rule, the thigh-bone is somewhat arched, and the shin-bone comparatively short and stout, in adaptation to the crouching gait; in upstanding modern man the thigh-bone is nearly straight.

If the theory of man's origin in an ape-like ancestor is well founded, the older the human skeletons that we find buried in the earth, the more closely they should approach ape-skeletons in the distinctive features just enumerated. Among the fossils there should indeed be "missing links." The study of other fossil animals leads us to suppose that we shall not find a single graduated series of missing links, but a multitude of forms of approach of the human frame to the ape-condition. We must infer, in short, that existing modern man is the triumphant survivor of many tentative advances towards a being with an overgrown and elaborate brain which should dominate and increasingly control the rest of nature.

Early Man in Java

The great difficulty is that very few remains of man's ancestors have been discovered which date back before the time when he had so far progressed as to acquire ideas of a future life and hence to bury his dead in security. Before that time, human remains could be preserved only when an individual happened to fall into a hole or into a river or lake where the body could be covered up with sand or

gravel or mud. Hitherto, the remains of not more than three such accidents have been discovered, and even in these cases only fragments of the skeletons have been preserved, so that we have very little material for the investigation of the subject.

The first of the discoveries of early man just mentioned was made by Professor Eugene Dubois in 1892, in an old river deposit in Java, which also contained the remains of extinct kinds of elephant and rhinoceros and other animals closely related to those still living in the East Indies. The principal fragment recovered is the top of a skull as large as that of a small man, with immense ape-like bony brow-ridges instead of the usual human forehead, but with impressions of a brain which is said to have been essentially human. Two associated teeth are not completely human, but in some ways resemble those of the little gibbon which still lives in the forests of Java. A thigh-bone, which is rather disappointing as being affected by disease at the upper end, is as straight as that of a man or a gibbon, and implies the possibility of an upright gait. If all these remains belong to one individual, as seems most probable, they represent either an ancestral man who approached the apes in his brow-ridges and teeth, or a gigantic gibbon which had an unusually enlarged brain. In any case, the being was well named *Pithecanthropus*—the ape man—by Professor Dubois, who was justified in claiming it as one of the "missing links." The specimens are now in the Teyler Museum at Haarlem, in Holland.

Heidelberg Man

The second discovery, which seems to date back to the time before man buried his dead, was made in a thick bed of sand deposited by a river at Mauer, near Heidelberg, in Germany, and was described by the late Professor Otto Schoetensack in 1907. It consists solely of a lower jaw, which was found in association with the bones and teeth of elephant, rhinoceros, hippopotamus and other animals which are known to have lived in Europe at the beginning of the Pleistocene period of geologists. The jaw is astonishingly large and massive, and, though essentially human, it differs from every known human jaw in the backward slope of the bony chin, which in this respect approaches that of the ape. At the same time, it contains typically human teeth in even series, without any enlargement or prominence of the canines. The fossil thus seems to represent an extinct species of man, *Homo heidelbergensis*, who still retained the retreating bony chin. It is now in the Geological Museum of the University of Heidelberg.

Piltdown Man.

The third very early accident to a primitive human being was revealed in an old river-gravel at Piltdown, Sussex, by the late Mr.

Charles Dawson in 1912. This gravel occurs in the Wealden country about midway between the southern chalk down and the sandstone ridge on which Crowborough is situated. It contains many water-worn flints which were derived from the chalk, and as no river in that part of Sussex could now bring them to the Piltdown district, it evidently dates back to a time when the local topography was entirely different from that of the present. It also contains fragments of elephant, hippopotamus and other animals, which show that it dates back at least to the beginning of the Pleistocene period.

The only fragments of a human skeleton hitherto discovered are the greater part of a skull and nearly half of a lower jaw with two molars and a canine tooth. The skull agrees with that in some existing low races of men in being remarkably thick, but it is unique in having a very fine spongy texture, which would make it highly resistant to blows. It is as destitute of bony brow-ridges as the skull of modern man, with a good forehead, but the crown of the head is less domed than usual, and the hinder or occipital part remarkably low and broad. The brain must have been essentially human, and it is distinctly larger than the smallest human brain of the present day; but it exhibits some peculiarities that are more suggestive of the ape pattern than any other human brain hitherto studied. The whole skull, indeed, is curious, and must have belonged to a human creature very different from modern man. The lower jaw is comparatively weak, but it is so much elongated that it implies a relatively large face. Its retreating bony chin is shaped almost exactly like that of an ape; it is much more ape-like than that of *Homo heidelbergensis*. The molar teeth, though essentially human, are unusually large and elongated; and the much-enlarged canine tooth is so worn as to show that it completely interlocked with the upper canine, as in an ape. This canine tooth, however, differs in shape from that of any known ape, and agrees best with the temporary (or milk) canine of modern man. It is certainly a tooth of the permanent series, and therefore represents the first or preliminary stage in the making of a typical human dentition.

Piltdown man indeed belongs to the real dawn of the human race, and has been appropriately named *Eoanthropus*, or dawn man. The original specimens, with fragments of a second skull and molar tooth discovered by Mr. Dawson in another locality near Piltdown, are now in the Geological Department of the British Museum (Natural History).

Neanderthal Man

The earliest form of man in Europe who was intentionally buried in security after death is now known by several more or less nearly complete skeletons from the caves and rock shelters of France and

Belgium. The first skeleton, of which only the top of the skull and a few other fragments were rescued from destruction, was found in the Neanderthal (or valley of the Neander) near Düsseldorf in Germany. The best French skeletons were found with flint implements of the peculiar pattern which is met with in the cave of Le Moustier in the Dordogne. The race represented is therefore commonly known as that of Neanderthal or Mousterian man.

The finest skeleton of Neanderthal man, which was described by Professor Marcellin Boule and is now in the National Museum of Natural History at Paris, was found in 1908 in a small cave near La Chapelle-aux-Saints in the Corrèze in S. W. France. The circumstances showed that it had been intentionally buried, while the associated flint implements and remains of woolly rhinoceros, reindeer, hyena and other animals proved its geological age. A leg of a bison, which must have been covered with flesh when it was buried, seems to have been placed there as food for the deceased in a future life. The skull is relatively the largest ever seen in healthy man, and the brain-case, which is curiously depressed and expanded behind, is larger than that of the average modern European. The brain, however, may have been inferior in quality. There are strongly inflated bony brow-ridges, as in an ape; and the face also slightly approaches that of an ape in being relatively large and in having no depression in the bony cheek beneath the eye. The mouth is also very large, but the teeth are in all respects typically human, and the bony chin only differs from that of modern man in being sharply truncated, not prominent near the lower edge. The backbone is remarkably stout, about two inches shorter than usual, and the man must have been of short stature. The arm is relatively long, and the two bones of the forearm are much arched, thus again retaining marked traces of an ape ancestry. The thigh bone is stouter and more bent than in ordinary man, and the shin bone is comparatively short and stout. While essentially human, therefore, Neanderthal man had probably a slouching rather than an upright gait, and his heavy face would give him a bestial aspect.

The Home of Modern Man

We may, then, pause to remark that the earliest known fossil remains of man approach the hypothetical ape ancestor in at least two distinct ways. In one case there are no bony brow-ridges, but an ape-like jaw; in the other case, there are great bony brow-ridges, but a typically human jaw. So far as the scanty evidence goes, it fulfils our expectation of finding more than one kind of "missing link."

In western Europe there is still no indication of typically modern man having lived with the immature grades of humanity just

described. All statements to the contrary are based on modern burials which have been wrongly interpreted. In the metropolis of early man in central France, however, typically human skeletons are found in deposits in the rock shelters and caves which are immediately above those containing the remains or handiwork of Neanderthal man. As no skeletons of an intermediate race have been discovered, it may therefore be inferred that modern man originated elsewhere and appeared as an immigrant in this part of the world. Indeed, all our present knowledge suggests that the successive phases of dawning humanity were passed through somewhere in the east, probably in south central Asia. In that case, the periodical westward migration of peoples which is so familiar a feature of historic times must have begun in remote prehistoric antiquity.

One reason for suspecting that south central Asia may have been the original home of man is that just before his beginning a very varied assemblage of great apes lived in the forests of northern India. They are unfortunately known only from a few scattered teeth and fragments of jaws found in the deposits of Miocene age which now form the Siwalik Hills, so that we have very little information about them; but no such series of great apes has hitherto been discovered elsewhere. Now, at the beginning of the Miocene period, the Himalayan Mountains did not exist, and (as the late Joseph Barrell first suggested) it may have been during the uplift of this mountain range at the end of the period that primitive man came into being. As the land rose, the temperature would be lowered, and some of the apes which had previously lived in the warm forest would be trapped to the north of the raised area. As comparatively dry plains would there take the place of forests, and as the apes could no longer migrate southwards, those that survived must have become adapted for living on the ground, and acquired carnivorous instead of frugivorous habits. By continued development of the brain and increase in bodily size, such ground apes would tend to become man.

The Natives of Australia and Tasmania

It has long been generally recognized that the lowest races of men in the present-day world are the blacks who inhabit Australia and those who until lately survived in Tasmania. They have often been regarded as closely related to the Neanderthal man who disappeared so long ago from Europe; but the discoveries of skeletons in France, already mentioned, show that the two races are entirely different. The remote lands of the southern hemisphere have always been the refuges in which old types of life have survived long after they became out of date and displaced in the more

progressive northern hemisphere. There is, however, still no evidence of the Neanderthal or any earlier race in the south, and the Australians and Tasmanians are probably the survivors of the true men of later Pleistocene times. Their immediate ancestors seem to have had a much wider range in the southern hemisphere at a recent period, for an Australoid skull is known from a rock shelter at Wadjate in Java, and another skull, associated with parts of the skeleton, which seems to have similar relationships, was found in 1921 buried in a cave in Northern Rhodesia. The Rhodesian skull, however, is unique in having the most inflated bony brow-ridges and the largest face ever seen in man. At first sight, these features seem more ape-like even than the corresponding parts of the European Neanderthal man; but more careful examination shows that the face is not enlarged on the ape model—the enlargement is not in the middle of the face, as in the ape, but round the edge—and the only known specimen which approaches the Rhodesian in the depth and extent of the bone below the nostril is a fossil Australian skull from Talgai in Queensland. In the characters of his brows and face, therefore, Rhodesian man probably exhibits merely a modern reversion to an ancient human type.

It may be added that man does not appear to have reached the American continent until much more recent times, for none of the fossil remains hitherto found in that region of the world differs essentially from the corresponding parts of the skeleton of the existing American Indians.

INSECT MIMICRY AND THE DARWINIAN THEORY OF NATURAL SELECTION

By Professor E. B. POULTON, F.R.S.

THE superficial resemblances between insects constantly attracted the attention of the older naturalists, as we realize from the names they gave when they called certain moths "bee-like," "wasp-like," etc. It was the same with resemblance to surroundings. The fine old naturalist, W. J. Burchell, writing more than a hundred years ago of his travels in the interior of South Africa, described a grasshopper which exactly resembled a stone and also fleshy plants of the Karoo which were hidden in the same way. He fully recognized the benefit conferred by this likeness, but held the common belief of his day that insect and plant came into existence exactly as we see them and that their resemblances were part of "the harmony with which they have been adapted by the Creator to each other and to the situations in which they are found."

The appearance of Darwin's "Origin of Species" in 1859 brought clear evidence that animals and plants had reached their present state by a process of evolution, and that the main motive cause had been natural selection or the survival of the fittest, acting upon hereditary variations. One of the first problems to which these principles came to be applied was insect mimicry and the protective resemblances or concealing colors and shapes of insects—both resemblances so widespread and evident in nature that the failure to explain them on Darwinian principles would have meant the breakdown of the principles themselves. Insect mimicry and insect concealment became test problems. If produced by natural selection these resemblances must be beneficial and must have been attained by transition from different and less beneficial stages.

It is necessary at the outset to clear away certain misconceptions which here arise from the word 'mimicry," used in ordinary speech to signify conscious imitation. As used technically for these deceptive superficial resemblances, conscious imitation is out of the question. No insect "by taking thought" can effect any change in its own appearance. Mimicry is akin to protective resemblance and is sometimes employed to include the latter; but it is convenient to keep the two separate because they lead to such different kinds of appearance. In mimicry, an insect resembles another, the model, which possesses some special defense, such as a sting, an unpleasant taste or smell, etc., and advertises its powers by conspicuous warning colors. The mimic therefore becomes itself conspicuous. In protective resemblance, on the contrary, an insect resembles something, such as earth or bark, of no interest to its enemies, and in resembling it becomes concealed.

Early Recognition of Mimicry

Returning to the relation between mimicry and natural selection, it must have been obvious to naturalists for many years that the resemblance of a stingless moth or fly to a bee or wasp is likely to be advantageous. It was otherwise with the likeness between many butterflies and day-flying moths collected by H. W. Bates in the Amazon Valley—striking likenesses of color and pattern in each locality, all changing together, "as it were with the touch of an enchanter's wand," in passing from one area to another. The late Dr. F. D. Godman has told us that Bates did not solve this problem in the tropics. The solution came after studying his collection at home and reflecting on his memories of the living insects. In November, 1861, just two years after the publication of the "Origin of Species," he read before the Linnean Society his classical paper in which it was shown that the imitated butterflies or "models" were specially abundant, conspicuous and slow-flying, and belonged

to groups with these characteristics, while the "mimics"—members of several widely separated groups—had departed from the colors and patterns still borne by their non-mimetic allies.

A few years later, in 1866, A. R. Wallace showed that Bates's interpretation was valid for the tropical east; and, again in a few years, Roland Trimen proved that it held in Africa. All three memoirs were published in the "Transactions" of the Linnean Society, and the last mentioned, appearing in 1870, showed for the first time that three swallowtail butterflies with entirely different patterns, and without "tails" to the hind wings, were the females of a fourth swallowtail which bore "tails" and was of a still more divergent pattern. All four had been described as different species. Trimen further showed that in Madagascar a closely allied male had a tailed female very like itself, and that on the mainland of Africa the "tails" had been lost and different patterns gained by the females in mimicry of three different species of the tailless group Danainæ which provides the chief models for mimicry in the east, and is closely allied to the chief models of tropical America.

Trimen's conclusions were received with incredulity, and indeed contempt by some of the older naturalists; but he lived to see them everywhere accepted, and put beyond the possibility of doubt by breeding the males and all three female forms in one family produced by a known female parent.

Types of Mimicry

Bates, in the great paper already referred to, directed attention to the fact that butterflies belonging to the groups which supply the models also mimic each other, and this puzzled him. The interpretation came in 1878, when Fritz Müller, a German naturalist living in Brazil and deeply influenced by the "Origin of Species" and by correspondence with Darwin, brought forward the theory which has since been known as Müllerian mimicry. He then showed the advantage of a resemblance between unpalatable conspicuous insects, because it reduces the number of warning patterns which must be learned by enemies and the number of injuries inflicted in learning them.

Batesian mimicry is like the action of a struggling unscrupulous firm which imitates the trade-mark or advertisement of a successful house. Müllerian mimicry is like the action of a group of powerful firms which become still better known at a lessened cost by combined advertisement.

The decision, whether any mimic is Batesian or Müllerian, is in some instances easy, in others difficult, and opinions are divided as to the relative importance of the two theories. When the allies of a mimetic species are well concealed by protective resemblances, then

the mimic is most probably Batesian; when the allies are specially protected and warningly colored, then the mimic is probably Müllerian, and has merely exchanged one warning pattern for another. Again, a large proportion of mimetic species are, like *Papilio dardanus*, only mimetic in the female sex, the original pattern of the female being retained by the male. Here the appearance of the male, and especially of its under-surface pattern, helps us to decide whether the female is a Batesian or a Müllerian mimic.

The prevalence of mimicry in the female was explained by A. R. Wallace by the greater needs of that sex—their greater weight and slower flight, and the necessity for them to alight and lay their eggs. Another cooperating explanation was suggested much later, namely, that the females are more variable than the males, and thus produce the requisite changes of pattern more freely.

Origin of Mimicry

There can be little doubt that Mendelian heredity has been of great importance in the origin of mimicry, diminishing the "swamping effect of inter-crossing" between the parent form and the incipient mimic and between the different fully formed mimics belonging to one species, as in *P. dardanus*. There is also a considerable body of facts which suggest that Mendelian heredity does actually operate in this and other mimetic species, the most complete evidence being that obtained by Mr. J. C. F. Fryer by his breeding experiments on *Papilio polytes*. This species in Ceylon, where the experiments were conducted, has three forms of female, one like the male and two resembling other swallowtails which belong to a distasteful group. The Mendelian relationship was found to exist between these three females.

It is in the facts of geographical distribution that we find the most conclusive evidence of the production of mimicry by natural selection. Two Danaine butterflies in America belong to an Old World group, and are evidently recent invaders by way of the north. In temperate North America they have met the natives of the Northern Belt, among them the white admirals, allied to our own well-known species *sybilla*. If, therefore, mimetic resemblance is, as some have supposed, the common result of common causes associated with locality, the invader ought to have come to resemble the ancient resident, but as a matter of fact the resident has lost its original pattern and mimics the invader. The change, although immense, so far as the pattern is concerned, is so superficial and recent that the early stages are entirely unaffected, and the mimic can interbreed with another unchanged North American white admiral, producing an intermediate hybrid—an experiment successfully carried out by Mr. W. L. W. Field.

The Pseudacræas of tropical Africa, nearly all of them mimetic in both sexes, are butterflies closely allied to the white admirals. A species in Uganda, *eurytus*, is a very complicated example of mimicry, for this single species includes in the same locality three different forms, two with sexes alike mimicking two Acraeine species with sexes alike, one with sexes different mimicking the corresponding sexes of another Acraeine. The fact that all these mimics are one species was proved by breeding by Dr. G. D. H. Carpenter. Now in Uganda intermediates between these three forms of *eurytus* are rare, whereas on some of the islands in Lake Victoria they are very common, and Dr. Carpenter, who proved this fact, found that on these same islands the models are, for some unknown reason, rarer than their mimics. The facts suggest strongly that there is more severe extinction of intermediates in the presence of abundant models, but less severe when models are few.

Butterflies and day-flying moths are especially suitable for the study of mimicry, because the resemblances are chiefly shown in the colors and patterns on the broad surface of their wings, both colors and patterns being very variable, and thus affording material for rapid change by the operation of natural selection. But the same phenomena are conspicuous in other groups of insects, such as the beetles. We find among the beetles, as among the butterflies and moths, that the models belong to the distasteful warningly colored groups, and that members of these tend to mimic each other, as well as to be mimicked by species of less powerful groups.

The most convincing evidence of the production of mimetic likeness by the operation of natural selection is provided by a comparison of the different methods by which a resemblance to formidable insects, such as wasps and ants, has been attained. The variations which present the possible beginnings of such a likeness are determined by the present constitution of each species, and this again has been determined by its past history. Great difference in the method of resemblance is therefore to be expected and is found. In some flies the slender "waist" of a wasp is represented by an actual narrowing of the body; in certain beetles by a patch of white which "paints out" the superfluous thickness—a device very elaborately carried out in the young stages of an African long-horned grasshopper, which lives among green leaves and has the un-antlike parts of its body colored green—the antlike parts black.

Mimicry in Movement

The likeness requires astonishing readjustments when the mimicking animal is widely different from its model. Thus many small

spiders mimic ants; but spiders are not insects, having no antennæ, eight legs instead of six, and the body divided into two sections instead of three. A North American spider observed by Dr. and Mrs. Pecklam got over these difficulties by holding up one pair of legs to represent antennæ and by developing a groove across one of the body sections, making it look like two.

Mimetic likeness to be efficient nearly always demands appropriate movements, and these are often the most important part of the likeness, and sometimes the probable starting-point. Thus beetles which in the cabinet do not at all closely resemble a wasp may be convincingly wasplike in the rapidity and jerkiness of their movements. This is true of our British wasp-beetle and of a rather similar Brazilian species of which Burchell wrote on his later South American journey nearly one hundred years ago: "It runs rapidly like an ichneumon or wasp, of which it has the appearance." A note by the same naturalist on a small Brazilian spider suggests that the first stage of mimicry was produced in this way: "Black . . . runs and seems like an ant with large extended jaws." Now this spider does not belong to a group known to include antlike species, and Burchell's observation suggests, as Mr. R. I. Pocock has pointed out, "that the perfect imitation in shape, as well as in movement, seen in many species was started in forms of an appropriate size and color by the mimicry of movements alone."

Natural Selection and the Production of Mimicry and Protective Resemblance

Of all the methods by which mimicry and protective resemblance also is produced, the most remarkable and the most convincing as evidence for the operation of natural selection is that followed by tropical American insects allied to the Cicadas and our too well-known greenfly. It is only because these insects—the Membracidæ—are all of them small that the examples are unfamiliar and the lessons they teach unknown to many who are interested in the subject. The body of these little insects is shaped much like that of the greenfly, but it is completely hidden when looked at from above by a covering shield, which is developed from the body-ring behind the head and grows backwards. Therefore, when the insect is concealed by resembling some object such as a thorn or mimics an ant, the deceptive likeness to be of any use must appear in the covering shield, and not in the hidden body; and this is exactly what has happened.

The criticism has been urged by Jacobi that these insects, when disturbed, leap like their relatives, the froghoppers, and therefore

the mimicry of an ant is meaningless. This is a good example of the kind of objection often raised against the theory of mimicry. But, if a hopping insect comes to resemble an ant, it still stands to gain by keeping its older means of escape when the newer one is seen through by an enemy.

Another objection often brought forward, especially against the theory of mimicry as applied to butterflies, is the assertion that these insects are rarely attacked, if at all, by birds—the only enemies which are believed to cause first the growth and then the maintenance of a deceptive resemblance to the model, by destroying on the average more of the unlike and less of the like in each generation. The critics have especially relied upon the insufficiency of direct evidence of such attacks, and the almost complete absence of butterfly remains from the stomachs of an immense number of American birds which were examined in order to determine the nature of their food.

In reply to the former objection, Dr. G. A. K. Marshall collected and published in 1909 all the observations recorded up to that date, and proved that the evidence was much stronger than had been supposed. Furthermore, attention having been thus directed to the subject, many naturalists, especially Mr. C. F. M. Swynnerton, Dr. G. D. H. Carpenter and Captain W. A. Lamborn, made a special study of the relation between birds and butterflies in various parts of Africa, and soon produced abundant positive evidence. Mr. Swynnerton and Captain Lamborn also directed attention to the frequent presence of birds' beak-marks upon the wings of butterflies, marks which afford the strongest circumstantial evidence of attack. Beautiful examples of these impressions of beaks on Fijian butterflies have still more recently been received from Mr. H. W. Simmonds.

As regards the objection founded on American birds, Mr. Swynnerton has proved, and Captain Lamborn has confirmed, that the digestion of birds is remarkably rapid, and that a butterfly is quickly reduced to a condition in which it can only be recognized by means of the compound microscope.

The facts of mimicry and protective resemblances are now patent to all, and no valid interpretation of these facts except that which is based on the theory of natural selection has ever been offered.

AN EVOLUTIONARY DEMOCRAT[1]

By Professor FREDERICK H. BLODGETT
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POLITICAL parties and their leaders may be thought of as examples of organization or activity among which response to environment may be expected to be the least evident, since leadership by the few rather than mutual influence of the many is the common condition. But a little while with a good history will show that even the safe and sane organization so widely recognized as the Grand Old Party, or its active associate with the flying heels and wagging ears, have responded to the influence of their environment from time to time, and have modified their aims, methods and modes of action.

A former secretary of state has been very active for some months, now amounting to several years, in an active, but intermittent attack upon what he thinks is meant among biologists by evolution, disregarding the fact that he is himself an example and product of the very forces which he so verbosely decries. The doctrines of the political party whose banner he has so many times upheld have undergone a very definite evolution, and his own attitude toward the principles worthy of a nation's support in party platforms or governmental policies has also been changed in accordance with the changes taking place in social conditions during the thirty years since he first advocated "Free Silver" and "Free Trade" as panaceas for discontent. This accomplished speaker of the prairie lands would be most unwilling to be charged with having made no advance in political development in this period or of having remained blind and unresponsive to the influence of the changes taking place all about him, in business, industry, social and political activities, and in the general increase in range of knowledge as represented by average high-school graduates of his home town.

Evolution has had its influence upon Mr. William Jennings Bryan quite as directly and definitely as upon *Pithecanthropus erectus*, but all the effect has been (so far as he individually is concerned) confined to the development of his own person and political ideas. But since mental and intellectual adjustments may be made much more readily and promptly than can structural changes, the fact that changes have taken place in both cases is really the critical

1 -ary, "Standard Dictionary def. 1, "connected with or pertaining to."

detail, rather than the exact period covering the changes induced as responses to environmental influences themselves not fixed or constant. Animals and plants undergo growth, climax and decline in their development from inception to extinction, and the same sequence may be traced in the example of political evolution just cited.

The biographical sketch in the New International Encyclopedia may be used as an unbiased basis for the events of the party activities of the man under consideration, and from this we learn that he came to public notice first as congressman for the district of Lincoln, Nebraska, during the silver agitation, 1891 to 1895, when his skill in oratory was turned toward the protective tariff and free silver. Response to environment was evident in the strengthening of his views along these two lines, for with the closer geographical relations he enjoyed toward the miners and mine-owners of silver, due to his residence in Nebraska, as contrasted to that likely to have been experienced by him had he remained in his native state of Illinois, he soon became one of the chief advocates of the "16 to 1" idea. As a Democrat, he was in harmony with his party concerning a tariff for revenue only, but as an individual in that party he responded (along with many others similarly situated, of course) to the local conditions developing in the Mountain States, where the development of silver mines had gone forward extensively, while cattle-raising had been developed in the nearby prairie states by similar groups of hardy citizens.

From a raw congressman, in 1891, to the Silver-tongued Orator of 1896, Mr. Bryan manifests the response of evolutionary influences in developing (rather than seriously modifying) tendencies already present, so that the "Crown of thorns and cross of gold" key-note of the Chicago Convention marked the climax in active constructive development in the political ideas of the individual who delivered that oration, as due to that particular group of influences. From that time for several years his attitude was one of defense of his views, or at least of presenting them in contrast to those of the opposite group of gold standard advocates. Organisms do not show readjustment immediately to changes in environment, and organizations made up of such complex organisms as are human beings in political party groups are not more prompt in principle than are lower forms. Economic adversity brings forth various crops of panaceas, some of which may persist for a considerable time as popular cries, even if without real value as curative measures. The western states, in which a considerable amount of the adversity in the years 1880 to 1890 was felt, were also the states in which silver was the important mining metal; if only this source of wealth could be unharmed, all would be well!

By 1895 this idea had developed to a war cry, and at the Chicago convention, July, 1896, free coinage of silver at 16 to 1 was the chief plank of the Democratic party platform and was endorsed with cheers by the Populists and by the National Silver Party in their respective conventions in St. Louis three weeks later. Mr. Bryan had become the champion of three parties differing in all essentials except the one common plank of Free Silver Coinage—an experience as a political candidate duplicated by none other in American history, since party lines have been sharply drawn.

In the development of living organisms time is a factor which needs to be considered but little, except for purposes of studying the record of their successive stages, for nature carries no watch, and is in no rush for subway or other short cuts to destination. Generations of biological types succeed each other in their slight modifications from the average form, as century passes into added century, and only the early and the late forms may show definite differences even then. In the case of political parties, made up of human beings and their ideas, the time factor is greatly accentuated, for volition, intent and intelligent direction combine to hasten any changes in either the environment or the living units upon which the environment may act. Evolution is a slow process among nature's own forms, but may be a rapid one among social beings of human grade intelligence.

One of Spencer's suggestions as to the development of the present population of the earth in biological forms is commonly expressed as "the survival of the fittest" which carries with it the corollary—"elimination of the unfit." In human society, the various forms of charity, the great range of occupational opportunities and the substitution of financial means for "fitness" in strictly competitive fields makes the application of this phrase often seem ridiculous, and to throw doubt upon its application in nature as a whole. Mr. Bryan as candidate for the presidency in 1896 for three political parties was at the climax point of his evolutionary development. The formative influences which had been developing his oratorical powers as a congressman just then reached their culmination, and his apparent fitness was recognized by the open endorsement of the parties whose candidate he became. But in the test against judgment of the population at large in the country, he was found unfit for the highest office of the land, and another case of success for the standard, defeat for spectacular form or individual was recorded. This is simply duplicating in social life of man what has occurred many times with lower animals, as with snails, for example, which have in different genera passed from simple through complex structures, only to complete the history by the survival of the inconspicuous and inelaborate forms of the original type.

Living things are able to continue to live under changing conditions because they can adjust themselves to the changes they experience, and they manifest evolution as they show in behavior or structure various adjustments to the changing environments. Mr. Bryan is a living being, he is influenced by the conditions under which he maintains his existence, even though he tries to find the most congenial of such conditions by changing from Illinois to Nebraska and thence to Florida as a place of residence and field of activity. In 1900, as he still lived in Nebraska, next door to the silver lodes of the Colorado mountains, he still advocated "Free Silver," though his associates in the convention forced him to divide his energies between this and "Imperialism," against which the chief plank was framed at the Indianapolis convention. But the country was not now in the condition of hardship that had given birth to the earlier cry, and "free silver" could not displace the "full dinner pail" as a call for voters in a nation through which prosperity was generally distributed. The Bryan factor in this campaign was possible through the holdover influence of past environment influences, just as with plants and animals; adaptations developed under particular conditions are not necessarily discarded when conditions are modified even to a striking degree, such as bringing a spiny cactus into a standard greenhouse—it still is a cactus. Having developed to his political blooming under "free silver" adversity, the peculiar twists of development continued present, even though prosperity displaced adversity in the valley of the Platte as elsewhere in the states. As an energetic editor in a growing city of a great agricultural state, Mr. Bryan kept in touch with conditions for another four years. But literary antennae and journalistic otoliths were not sufficient to keep the silver-tongued orator in the position of leader for his party, and the convention of 1904 was so fully in tune with the country-wide prosperity that it definitely defeated the nomination of the western candidate and accepted one from the capitalistic and gold-standard region of New York in the person of Judge Alton B. Parker.

Four years more of the full dinner pail and general farm prosperity brings the date of 1908 to the calendar, and the recent developments of government oversight and control were much along the lines of the imperialistic tendencies against which the Democratic party had so loudly shouted in 1900. Bryan responded to the continued influence of the anti-imperialistic attitude of his own party leaders as well as tending to develop this into an effective weapon for campaign purposes, but found much of his thunder lacking in rumble because of the vigor of Roosevelt in curbing great trusts. Bryan as Democratic candidate made less stir than did

Hearst as Independent and was allowed to return to Lincoln after Taft's inauguration to resume the editorship of the *Commoner*. This period in his political life illustrates the general condition noted among plants and animals in many cases, that when the conditions under which they are kept are changed frequently, but not greatly in any case, little definite adaptation takes place toward any one of these, but an average—which approaches the former general condition—among the possible responses is found which serves as developmental factor for the organism. After the "free silver" period had been superseded by later prosperity, the absence of any real issue upon which to challenge the country at large acted upon the potential leadership of Mr. Bryan much as a period of minor fluctuations of environment on other domesticated animals—he just dropped to the general level of the average.

The country as a whole had been under more nearly uniform influences after 1900 than for a very long period before that date, and had come to stand for similar ideals as to political and business activities in both the great political parties. So that when the Democratic Convention of 1912 was called in Baltimore, there was less to choose between as to the platform and candidate of one or the other party than at most such occasions. By obstruction, rather than by support, Bryan at this convention controlled the balloting until the nomination of Woodrow Wilson was made after other candidates had been one after another withdrawn during forty-five ballots. But no definite influences had been working upon the political field during the decade, and neither the Republican nor the Democratic party had a platform which had direct appeal to the people by contrasting principles or panacea suggestions. The general principle of government oversight of great enterprises was accepted by the leaders of both parties, and new ideas were few.

Mr. Bryan, under these conditions of general prosperity for all parties, behaved just as other forms of life have done in repeated eras of geological history—when the living conditions assume a relatively fixed character, diversities and new developments drop to a minimum, as compared to periods when rapid changes of land and water areas, with the accompanying changes in temperature of both terrestrial and aquatic habitats, stimulate adjustments to meet such changes among plant and animal forms, which we call new species. During the period from the surrender at Appomattox to 1895 the political and economic conditions of this country (and others) were undergoing great changes, the several steps of which followed in quick succession. The opening of the great western plains and prairies to settlement, the development of mining in the mountain area, and the stimulus to speculative expansion these factors gave

the country, all acted as environmental changes upon the political organism, and the parties of the nation, with their several champions, responded with rapidly developed adjustments. New political parties, with various panaceas for the unbalanced economic conditions which resulted from the over-stimulus of western resources, came upon the scene, just as in geological eras new types of plant or animal appeared when conditions changed in any great degree from those of previous periods. In the geological record, we find in any of the several periods some type dominant over others, the dominant form being for the time better fitted to the living conditions existing than are the older forms. But characteristic or briefly dominant as such forms may be for their several eras, not all are so fortunate as to leave a creative impress upon later development, even of their own type of organism. The Trilobite is a good example of this, for it developed to a dominating position by the middle of the Ordovician period, when it was not only numerous but elaborately ornamented, indicating a surplus of energy beyond that required for mere living conditions. Its decline was, however, rapid and the "Horseshoe Crab" is the only form in any appreciable manner resembling this group of ancestors, of the modern crustaceans. In the field of political history, we find individuals and parties at critical times coming into active being, championing one or another structural detail from the possible panaceas for real or imagined ills, and individuals arising with the elaborate ornamentation of vigorous health and ready response to environment acting on the general nature of the organism to develop a new species among the less well-differentiated run of the general forms. But when the conditions, the stimulus of which was responsible for the development of such spectacular forms, themselves become adjusted to later changes in geological history or in national politics, then the striking examples of evolution which may have marked the period just preceding, drop into the background, become unimportant as to their characteristics, and finally disappear as active factors in further history.

With the evolutionary forces of the last forty years acting upon a human brain, rather than upon unintelligent animal forms, the time required for changes has been but a small fraction of normal. But the fact of evolutionary response to such environments can hardly be denied in such a case, any more than in the case of Eohippus, as he adapted himself to the increasingly hard forage plants and dry ground which defined the next step in his progress toward a full grown horse.

Mr. Bryan reached the climax of his career when as candidate for the presidency in three political parties at the same time, he ran as Free Silver champion in 1896; his climax was not a sharp peak of popularity, however, and the decline curve is quite gentle until general prosperity in the west as well as in the east made the interests of the two sections more in harmony. As in so many instances of distribution a revival of development or of influence is noted after the main climax has passed, so in 1908 Bryan showed his vitality by being nominated on the Democratic ticket to run with Kern against Taft and Sherman. But he did not fit into his environment—as judged by the votes of the people—and the Silver-tongued Orator of the Platte was returned to editorial desk of the *Commoner*, while a candidate fitting more closely the new conditions of the country's rapid development went to the White House.

Extinction has come to many forms of plant and animal life because of the retention of adaptative structures beyond the time during which they were of direct service to the organism concerned. The saber-toothed tiger did splendidly for many a century when the long canines were the best aids to good living yet devised, but even these at last proved to be too much of a good thing, and he seems to have starved to death by the over-development of these very teeth, barring food from his jaws.

In the case under consideration, the climax in misfitness came when, as secretary of state, an adjustment from the promulgation of treaties of arbitration to an active attitude toward atrocities was found impossible and the very ideas which under slightly different form had been the chief factor in his policy became the disqualifying detail under pressure of actual emergency. Resigning from his post because he no longer even approximately "fitted" his environment, the one-time champion of "free silver" dropped to the background of his party and devoted his energies to newspaper activities and the lecture platform.

Agitation concerning the teaching of evolution of animal and plant forms seemed to this fluent orator as good a field for his activities as had the "free silver" and related ideas twenty years before. Unfortunately, the orator did not first become familiar with his subject, but took at second hand or even less directly the points which he used in his flowery flights of denunciation. Using his own judgment as a sufficient basis for statement and disregarding the applications of the principles of adaptation among plants and animals, of which there are scores of instances among the plants and animals of the western prairies, both in wild life and farm products, Mr. Bryan simply harangues in catch phrases of much sound but

little sense, judging from reported utterances. (As when he compares the "milk" of cocoanut, of milkweed and of cows, as a challenge to show evolution!)

Evolution is simply the unfolding and developing of capacities and adaptations in plant and animal forms under the influence of changes in the conditions under which one or another may be living. Mr. Bryan has undergone similar influences during his political career, and he would be among the first to question the statement that he had not shown responsive adaptations to these changing conditions; that is, to have manifested "evolution" in his own political development and personal history. His long political life has made possible a greater manifestation of evolution of this kind than falls to the lot of most men, but the response to environment is quite as truly present as if he personally believed in the biologist's theory and could cite examples galore.

THE READING OF GRADUATE STUDENTS[1]

By Professor RAYMOND PEARL
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In theory, at least, that special kind of intellectual activity which we call graduate study and in so doing emphasize the least important of its milestones, should give its practitioner a comprehensive, justly balanced and critically related knowledge of the particular field whose charms have seduced him. Perhaps I ought more precisely to say that this was the theory in my youth, and is still clung to by some. But the prevalence and power of this view are unmistakably diminishing. This is perhaps chiefly because of the closer and closer integration of the advanced and graduate activities in our universities with the rest of the highly formalized and mechanized system of education which prevails in the land and is in such perfect accord with the cultivation of that efficient, standardized mediocrity which seems to be the very spirit and genius of American civilization. It is now quite possible, in fact it probably has been done, for a boy to go straight through from his letter blocks to his Ph.D. with precisely the same kind of cooperation in the enterprise on his part that a sardine furnishes to the business of his translation from the state of innocence and freedom of his birthplace to the diploma-bearing tin on the grocer's shelf. All that is requisite is a certain self-effacing conformity to a series of propulsive mechanisms.

Perhaps this is as it should be. Certainly he is a rash person who attempts to stand athwart the current of his civilization. But without being so extreme in the matter as this would imply the idea still somewhat widely prevails that, without interfering in any important way with the smoothness of the established methods of manufacturing doctors of philosophy, and without curtailing the output of this commodity, it is desirable, and should be possible, to make the *graduate* student take a more active personal interest in the process of his transfiguration than the sardine may be presumed to. During the quarter of a century that I have tried to function as an insignificant cog in certain of the mechanisms referred to, the problem of how best to make those machines more useful has intermittently but still extensively engaged my attention. The instinct of workmanship is fairly deep-seated. We all like to do as good a job as we can. It has fallen out that my duties

[1] Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University. No. 116.

have been mainly to aid in the progress of graduate students along their appointed chutes. The problem has been: How may that basic ideal of graduate instruction stated in the first sentence of this paper best be promoted? Not solely by lectures, it is generally agreed. There are two fundamental objections to this method; the first that it would make insufferable inroads on the professors' diversions, the other that it tends to perpetuate the intellectual inertia begotten in the student's undergraduate course.

The only other way yet heard of to accomplish the end sought is that known as directed reading. The instructor is supposed to outline a course of reading for the student which will make him privy to at least the major secrets of his subject. The advantages of this method are obvious. The student does something for himself. At its best he gets the sense of professional craft solidarity. He becomes really initiate into the realm of scholarship and makes contact with the great minds that have built the structure whose architecture he must know before he can add his bit to it. At the worst he has satisfied a requirement of the manufacturing process with a minimum amount of trouble to his instructor.

But granting the fundamental soundness of the pedagogical device of directed reading for graduate students, there still remains the problem for the instructor of determining on a general principle for the guiding of this reading. Obviously the student can not read in the three years of his graduate study as much of his subject as the instructor has in the, let us say, *n* years of his professional life. A selection must be made from the treasures at command. But upon what principle shall this selection be made? It is this question which has vexed my mind, and I fancy that of many another in similar position. What I used to do was to make out lists of highly technical researches in the particular field of interest and tell the student that along that pathway was the road to salvation. This I am sure was a mistake. It started from a false assumption. The progression was forthwith to the special on the supposition that the general had been taken care of. But nothing could be more ridiculous nonsense than such an assumption. In consequence of the widely prevailing pedagogical theory that needlework, jigsawing, salesmanship and many other kindred academic disciplines are of at least equal cultural and intellectual value in the training of our youth to the study of Greek or Latin or mathematics or chemistry; coupled with the permission, if not active encouragement to the undergraduate to specialize during his mental infancy, it results that when the young things begin serious graduate work a solidly grounded general cultural background upon which to build a sound specialism is precisely what, generally speaking, they most completely lack.

What then to do? Plainly the obligation is to repair as much as may be of the damage that has been wrought from omission and commission, by putting in the way of the student the means of orienting himself relative to his subject on the one hand and to the general *corpus* of human learning on the other hand. If he is any good—I mean any *real* good—he will then guide himself to the technical reading in his chosen special subject better than any one else can do it for him. If he is not any good—I mean again any *real* good—no harm will have been done. He will at least have glimpsed some little part of the evidence that

> Man's mind a mirror is of heavenly sights,
> A brief wherein all marvels summèd lie,

and in all probability will ever after lead a better life, even though he fails to become much of a biologist or biometrician.

After thought, and the application of the method of trial and error, I have evolved the course of reading for my graduate students which it is the purpose of this paper to exhibit. At the outstart it should be explained that the students for whom this list is primarily designed are looking forward, for the most part, to careers connected in some manner near or remote with public health. Mainly they want to become qualified vital statisticians or biometricians. Some regard academic halls as the optimum environment for their souls' ultimate expansion; others look forward to a career of usefulness in an official bureau or an independent research institution. All intend, bless their innocent hearts, to become investigators, researchers, small or great as *Allah* may will, but anyhow members in good standing of the holy brotherhood of those curious to know. All these considerations have played their due part in the making of the list. But what has been of the greatest importance in determining its final constitution is that public health, vital statistics and biometry are all, when properly viewed, parts or branches of *biology*. Naturally, if one were making such a list for an embryo physicist or chemist some of the items on the present would be replaced with others more directly pertinent to those lines of endeavor. But not all would be so replaced. A certain philosophical generality which taints and savors the list as a whole is perhaps its most engaging feature. Just as it stands it would do no harm to the graduate student of zoology or botany, particularly if he chanced to be interested in the problem of organic evolution. In fact, the student of evolution generally would be a good deal better off if he knew more about vital statistics than, except in rare instances, he now does.

The list is divided into three main parts on the following philosophy. Any person who intends to make his living and to spend

his life at science plainly ought first of all to have the clearest possible understanding as to what science is and what it is all about, in a broad philosophical and *human* sense. Such an understanding should come early in the course of professional scientific study. Perhaps the student is embarking on a scientific career under a misapprehension as to what science really is. Such cases have been known. They are always sad and may be tragic. Hence Section A, "The Nature, Meaning and Method of Science."

Because a person, from however pure and noble motives, elects to be a worker in science he is not thereby absolved from the duties and privileges of being human. He must work out an adjustment between the claims upon his life of his science, a proverbially jealous and exacting mistress, and those of the rest of the world, including not only deans, committees, commissioners, directors, boards, foundations and other great cosmic elements, but also cooks, maids, nurses, children and most important of all, his wife. While no one else can make these adjustments for him, still it will help to know how others have met the problem. Again if our graduate student, in whose behalf we are taking all this trouble, turns out to amount to much he will sooner or later receive offers for the purchase of his soul. Such offers will be made by those skilled in the traffic and they will be tempting. A little knowledge of the technique in these matters will not be amiss. Shall we not be derelict in our job of helping our student to get his training for life if we do not furnish him some insight into what wisdom is available about the making of these necessary adjustments between scientific research and the rest of life? I think so. Hence Section B, "The Conduct of Life."

Finally, and more obviously, my student is going to earn his living by the practice of a particular scientific trade. Hence Section C, "Vital Statistics."

I attach great importance to the order of the several items in the list. The maximum effect will be produced by reading them in precisely the sequence in which they are here set down, I believe.

(A) The Nature, Meaning and Method of Science

(1) Lucretius. *De Rerum Naturae.* Since few persons in this day and age can by any chance read this great poem about the problems with which science deals in the original Latin, I hasten to point out that certainly the handiest and perhaps on the whole the best translation for the purposes of the student of science not interested in the *minutiae* of textual criticism is the one published in Everyman's Library. (New York; E. P. Dutton & Co.).

(2) Seneca. *Quaestiones Naturales.* Undoubtedly the best translation for our purposes of this classic by a great man, who fur-

nishes the first example in a long series of the dreadful consequences of mixing science and politics, is that by John Clarke, entitled "Physical Science in the Time of Nero," London (Macmillan & Co.), 1910. The translation is intelligently accurate, and the edition is enhanced in value by the notes of Sir Archibald Geikie.

(3) ARISTOTLE. *Historia Animalium.* Beyond any comparison the best translation of this biological classic is that by D'Arcy Wentworth Thompson, which forms Volume IV of "The Works of Aristotle. Translated into English under the Editorship of J. A. Smith and W. D. Rose." Oxford (Clarendon Press), 1910. From the present point of view it is a pity that the annotations on biological matters are so meager in comparison with those on textual points, in this otherwise excellent edition. Gordon Alexander has recently (*Science,* March 13, 1925) called attention to a French translation of the *Historia Animalium* by Armand Gaston Camus (published in Paris, 1783) which supplies, by extensive biological notes, the deficiency mentioned in D'Arcy Tmompson's translation.

(4) LAWRENCE J. HENDERSON. *The Order of Nature.* Cambridge (Harvard University Press), 1917. This brief but important treatise will make it clear to the student, if it is not already so, why he has been asked to read the three preceding references. Further it will acquaint him early with *the* fundamental problem of science.

(5) LUCIAN OF SAMOSATA, *Vitarum auctio* and *Piscator.* These dialogues are included at this point to aid the student in properly orienting himself in respect of the rather weighty philosophical matters that have constituted so large a portion of his *pabulum* up to this point in the proceedings. He will find Lucian's account of the auctioning of the creeds, and its consequences, an agreeable corrective to any tendency towards mental coarctation or impedition which may have developed. While I refer here specifically to but two of Lucian's works, it is always to be hoped that this sample will whet his appetite for more, and that the student will read this too much neglected author extensively. Regarding translations I can recommend as the raciest rendering of Lucian in English "The Works of Lucian of Samosata." Translated by H. W. Fowler and F. G. Fowler. 4 Vols. Oxford (Clarendon Press), 1905. The volumes are of a handy size, and I find I take it from my library shelf oftener than any other edition of Lucian. Its only fault is a somewhat heavier expurgation than robust biologists will find necessary.

The works listed up to this point may fairly be said, I think, to expose within their limits the field of science as a whole in its philosophical meaning and relationships. He who has read through

these five titles can not fail to be impressed with the nobility and grandeur of the enterprise upon which he has embarked in deciding to devote his life to science.

We may next properly consider in some detail, but also with generality, the *method* of science.

(6) Francis Bacon. *On the Dignity and Advancement of Learning* and *Novum Organum; or True Suggestion for the Interpretation of Nature.* Our student will talk and hear a great deal about the Baconian method. It is reasonable that he find out at first hand what it is. Also his eyes will be helpfully (and widely) opened in various other directions by reading these two books.

(7) René Descartes. *Discours de la méthode pour bien conduire sa raison et chercher la vérité dans les sciences.* This great classic on the method of science has been translated into many languages. The student may read it in any he likes.

(8) William Whewell. *The History of the Inductive Sciences.* While never, so far as I am aware, characterized as light reading, there is nothing to this day to take the place of this treatise. A supplement or sequel to it ought to be done. It formed in Whewell's own mind only the first half of his *magnum opus,* but I have never had the courage—even if I had had the desire—to ask any young and cheerful student to wade through that preternaturally dull and in good part quite unsound book, "The Philosophy of the Inductive Sciences, formed upon their History." It may be said, however, that there is a certain amount of entertainment and profit to be derived from the "Aphorisms" in Volume II.

(9) Gustave Flaubert. *Bouvard et Pécuchet.* This I conceive to be one of the most important titles in the whole list. Its outlook on life and learning is *essentially* that of "The Education of Henry Adams," but it is a much more entertaining book. And at just this point, after the very solid meat of Whewell, something in the nature of an acation is needed.

(10) Karl Pearson. *The Grammar of Science.* I like best the second edition. I am told by some of my friends that this is not a great book, that it lacks originality and fails in other ways I can not now remember. Perhaps so. I first read it the year I began graduate work. It produced at that time such an effect on my intellectual outlook as no other book I had ever read. Henry Adams reports that Willard Gibbs said he found it helpful. I know of no other single book quite so important for the student beginning graduate work in science to read.

(11) F. C. S. Schiller. *Formal Logic, a Scientific and Social Problem.* London (Macmillan & Co.), 1912. Logic is a necessary part of the methodological equipment of the man of science. But it is in some respects the most tricky and dangerous tool in the box. Schiller is a sound guide.

Most of my students look forward to a lifework in a universe of discourse in which the chief objective realities will be medical and biological matters. On this account it seems reasonable that they have a glimpse at least of certain philosophical and historical aspects of these fields.

(12) GALEN. *On the Natural Faculties.* Every medical student hears of Galen. Few read him. The most satisfactory edition readily available is that in the Loeb Classical Library, the translation being done by a medical man, Dr. Arthur John Brock.

(13) ARTHUR TILLEY. *Francois Rabelais,* Philadelphia (Lippincott), 1907. This book is an intercalation which theoretically ought not to have to be here. It is inserted simply as a preparation for the next item on the list. Many persons find it difficult to get anything like a proper appreciation and respect for the significance of Rabelais in the history of thought when they approach his works wholly unprepared. One needs to know something of his times and the circumstances of his life. Tilley's commentary is sound and helpful.

(14) FRANCOIS RABELAIS. *Five books of the Lives, Heroick Deeds and Sayings of Gargantua and his Sonne Pantagruel.* Of this great classic there are innumerable editions. In the original it is difficult for any one not a specialist in medieval French. But the English translation begun by Sir Thomas Urquhart and finished by Pierre Motteux has become a classic on its own account. Of the various editions in my collection I will mention only these: First the Navarre Society's two column edition recently issued, with illustrations by W. Heath Robinson. To those who know Rabelais and Heath Robinson further comment is unnecessary. The typography and printing of this edition are beautiful. But the volumes are too bulky for the travelling bag, and the edition lacks Motteux's notes which are valuable. For everyday use I find a little five volume edition published in London, edited by Alfred Wallis, to be very convenient.

(15) WILLIAM HARVEY. *An Anatomical Disquisition on the Motion of the Heart and Blood in Animals.* The Everyman edition is excellent.

(16) WILLIAM MADDOCK BAYLISS. *Principles of General Physiology.* Probably there is no other single book which so wisely, justly and philosophically sets forth what is known of the general principles of biology. I like best the original edition.

(B) THE CONDUCT OF LIFE

(17) ARTHUR SCHOPENHAUER. *Parerga und Paralipomena.* In this collection of essays the one especially referred to here is *"Aphorismen zur Lebensweisheit."* Selected papers from this col-

lection were translated by T. B. Saunders in his "Essays of Schopenhauer." The most important parts, for the present purpose, of the *Lebensweisheit* are given in this translation as "The Wisdom of Life" and "Counsels and Maxims." In steering a pleasant and successful voyage through the tortuous and perilous channels of the sea of life in the real world of to-day the student will find few guides so sound and practical as this essay, because it will clarify his vision as to where the perils lie. It is of course to be hoped that this introduction to Schopenhauer will tempt the student to read his great contribution to philosophical thought *Die Welt als Wille und Vorstellung.*

(18) H. L. MENCKEN. *Prejudices.* Series I to IV inclusive. New York (Knopf). Along with some matter perhaps irrelevant to the present purpose these essays contain much ripe wisdom about the more important aspects of the technique and ethics of civilized living.

(19) *Jerome Cardan—The Life of Girolamo Cardano, of Milan, Physician.* By HENRY MORLEY, London. (Chapman and Hall), 1854, 2 vols. In building up a useful working knowledge of human behavior there is much in favor of the same pedagogical method that has been found so valuable in other branches of zoology, namely, the careful study of type specimens. The short series which can be included here starts with Cardan. He was, on the whole, probably the most distinguished mathematician and the most distinguished physician of his day. This combination should interest the budding biometrician. His life was quite as melodramatically thrilling as that of Benvenuto Cellini.

(20) *Memoirs of the Life, Writings and Discoveries of Sir Isaac Newton.* By Sir DAVID BREWSTER. Edinburgh (Constable), 1855. 2 vols. Two individuals more completely unlike in certain respects than Cardan and Newton probably never existed. But in certain human reactions to their work they were very like indeed.

(21) *Memoir of Augustus De Morgan,* by his wife, SOPHIA ELIZABETH DE MORGAN. London (Longmans, Green), 1882. The reasons for inserting this and the next few items are so obvious as not to require comment.

(22) HUGH MILLER. *My Schools and Schoolmasters, or the Story of my Education.* My copy is of the 13th edition, and dated Edinburgh 1869. To our mentally and financially becoddled fellowshippees of the present day this book must seem like some prehistoric fairy tale.

(23) *The Life and Letters of Charles Darwin, Including an Autobiographical Chapter.* Edited by his son FRANCIS DARWIN. 3 Vols. London, 1887. If this life, with its perfect devotion to the

highest ideals of science, does not prove an inspiration to the student, he is hopeless.

(24) *Samuel Butler Author of Erewhon* (1835–1902). *A Memoir by Henry Festing Jones.* London (Macmillan), 1919. 2 Vols.

(25) *Quetelet—Statisticien et Sociologue.* By J. LOTTIN, Louvain and Paris, 1912.

(26) FRANCIS GALTON. *Memories of my Life.* New York (E. P. Dutton & Co.), 1909.

(27) KARL PEARSON. *The Life, Letters and Labours of Francis Galton.* Vol. I. Birth 1822 to Marriage 1853. Cambridge (University Press), 1914. Vol. II. Researches of Middle Life. Cambridge (University Press), 1924. This great biography by Pearson is inserted in this list in addition to Galton's own autobiography because of its very great technical value to the biometrician. It contains a wealth of suggestive ideas.

(28) RENÉ VALLERY-RADOT. *The Life of Pasteur.* Easily available in either French or English.

Room lacks for more specimens of really sapient human beings. There are many other matters which must be covered in this reading list. But one always hopes that these few choice samples will develop a taste for biographical reading. We turn now to other considerations.

(29) ANATOLE FRANCE. *Le mannequin d'osier.* Our student may have thoughts of a career as a college or university teacher. He ought to know something of the inwardness of such a life.

(30) WILLIAM MORTON WHEELER. *The termitodoxa, or biology and society* (SCIENTIFIC MONTHLY, February 1920, pp. 113–124) and *The dry-rot of our academic biology.* (*Science,* Vol. 57, pp. 61–71, 1923.) These two items have the same purpose in our scheme as the preceding, No. 29.

(31) FRANCOIS MARIE AROUET DE VOLTAIRE. *Micromegas.* This should be read frequently—it is short—from youth on, as a powerful protection against the ever-present danger of becoming seriously important—or importantly serious. This peril threatens all mankind, but especially professors and public officials.

(32) JAMES BRANCH CABELL. *Straws and Prayer-books. Dizain des Diversions.* New York (McBride), 1924. To the end that the student may observe the working of the mind of an artist, and see the great similarities and small differences between original creative effort in art and in science.

(C) BIOMETRY AND VITAL STATISTICS

(33) CHARLES DARWIN. *The Origin of Species* and *The Descent of Man.* No better introduction than these two books to the mode

of reasoning fundamental to sound statistical procedures can be found.

(34) WILLIAM W. KEEN. *I Believe in God and in Evolution,* and *Everlasting Life; a Creed and a Speculation.* Philadelphia (J. B. Lippincott Co.). These two books should be read immediately after Darwin. The student will see how a sincere and orthodox religious faith may be brought into the fullest reconciliation and harmony with the latest developments of science.

(35) JOHN GRAUNT. *Natural and Political Observations Mentioned in a following Index, and made upon the Bills of Mortality.* 1662. The first treatise on vital statistics. For student reading the extremely well-edited and annotated reprint of this classic in C. H. Hull's "The Economic Writings of Sir William Petty, etc." 1899, is the edition of choice.

(36) T. R. MALTHUS. *Essay on the Principle of Population as it Affects the Future Improvement of Society.* 1798. The Everyman Library edition, which is a reprint of the seventh edition of the original work, is excellent.

(37) A. N. WHITEHEAD. *An Introduction to Mathematics.* New York and London (Home University Library), 1911. This little treatise has served admirably two useful purposes in my laboratory ever since its appearance. First to dispel mathematicophobia when present, and second to demonstrate to the average student fresh from undergraduate mathematics, as taught in our colleges and universities, that the intellectual content of that subject extends beyond puzzle-solving.

(38) ISAAC TODHUNTER. *A History of the Mathematical Theory of Probability from the Time of Pascal to that of Laplace.* Cambridge and London (Macmillan & Co.), 1865. To be regarded, in all reverence, as the Bible (revised version) of the subject.

(39) CHARLES S. PEIRCE. *A Theory of Probable Inference.* In Studies in Logic by Members of the Johns Hopkins University. Boston, 1883, pp. 126–181. This is a classic. No student of statistics can properly be said to have laid his basic foundations till he has mastered this essay.

(40) WILLIAM FARR. *Vital Statistics: A Memorial Volume of Selections from the Reports and Writings of William Farr, M.D., D.C.L., C.B., F.R.S. Edited by Noel A. Humphreys.* London, 1885. This may profitably be supplemented by delving in the Registrar General's Reports, because Humphreys by no means extracted all the meat from the writings of the greatest medical statistician who has lived.

(41) FRANCIS GALTON. *Natural Inheritance* and *Inquiries into Human Faculty and its Development.* Two great statistical classics.

(42) LAHMAN FORREST BROWN. *The Economic Waste of Sin.* New York (Abingdon Press), 1924. This book is introduced in

order that the student may study a nearly perfect specimen of a significant modern, indeed post-war, development of statistical "science,"* namely, the use of what is conceived to be the statistical method in the *service* (*sensu Rotarianismo*) of humanity, to uplift us all, help us to lead a purer and nobler life and in general do somebody good. All present signs indicate that this branch of statistics offers by a considerable margin the most lucrative career of any in the profession. As its technique is but little taught in the higher seats of learning perhaps it is only fair that the student should be directed to a prize example.

(43) KNUD FABER. *Nosography in Modern Internal Medicine.* London (Oxford University Press), 1923. An excellent brief history *not* of medicine but of medical *ideas.*

(44) ERWIN BAUR, EUGEN FISCHER, FRITZ LENZ. *Menschliche Erblichkeitslehre.* München (J. F. Lehmanns Verlag), 1923. That the student may know something of the modern science of genetics in its relation to man.

(45) JULIUS BAUER. *Die konstitutionelle Disposition zu inneren Krankheiten.* Berlin (Julius Springer). That it may become even clearer that genetics has relation to medicine.

(46) WILLIAM G. MACCALLUM. *A Text Book of Pathology.* Philadelphia (W. B. Saunders Co.). So that if our student becomes a practicing vital statistician he may have a less vague notion than he otherwise might of the objective realities which lie behind the statements as to causes of death which appear upon death certificates.

(47) WILLIAM TRAVIS HOWARD, JR. *Public Health Administration and the Natural History of Disease in Baltimore, Maryland, 1797–1920.* Washington (Carnegie Institution, Publication No. 351), 1924. To the end that the time base and other elements of his thinking about public health problems may be expanded, if by chance our student is interested in public health.

(48) G. UDNY YULE. *An Introduction to the Theory of Statistics.* Seventh Edition. London (Griffin & Co.), 1924. This book ends the list, not because the student will not have made contact with it sooner, but because it will be desirable to reread at this terminal stage a book which in my judgment embodies and exemplifies, in a degree that no other I know of does, a sound, well-ripened philosophy of the statistical method.

Little needs to be said in the way of epilogue. Doubtless this list of reading will be violently criticized by some. But so probably would any other list. The real test of its value is the effect which the reading of the books in it produces upon the minds of graduate students. As to the outcome of such a test I am not greatly worried.

* So to speak.

THE NEW IMMIGRATION LAW AND ITS OPERATION

By Professor ROBERT DE C. WARD

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WHAT were the objects of the immigration act of 1924? How far are those objects being accomplished? What changes or improvements are suggested by our experience with the operation of the new act since July 1 last?

The main provisions of this law may be classified under three heads, *viz.*, (1) limitation of numbers and allotment of the quotas; (2) preliminary selection overseas; (3) provisions based on humanitarian motives.

(1) LIMITATION OF NUMBERS AND ALLOTMENT OF QUOTAS

The annual quota (until June 30, 1927) is 2 per cent. of the number of foreign-born of each nationality in this country in 1890. This allows between 160,000 and 170,000 new alien immigrants to come in annually, by far the majority of them from Europe. Immigrants born in countries of the western hemisphere and their wives and unmarried children under 18, if accompanying or following them, can come in without limitation as to numbers provided they are not excludable on physical, mental or moral grounds under the general immigration act of 1917.

The first quota act, that of 1921, now superseded, limited immigration to 3 per cent. of the foreign-born living in the United States at the time of the 1910 census. This gave the countries of southern and eastern Europe, together with Asiatic Turkey and Palestine, nearly 50 per cent. of the total immigration, although the natives of those countries now in the United States constitute only about 15 per cent. of the total white population. The 2 per cent. percentage provision in the new law (using the census base of 1890) gives southern and eastern Europe and near-Asia roughly the same proportion of the total immigration as the natives of those countries now in the United States bear to our total population. Yet certain groups composed of recent immigrants from southern and eastern Europe are demanding larger quotas on the ground that they are not getting a "fair share" of immigration. They claim that the present immigration law "discriminates" against them. If the percentage law can be said to discriminate at all, ***the element against***

which there is discrimination is the native-born American, for the quota percentages, it must be remembered, are based solely on the numbers of *foreign-born* in the United States in 1890. This law recognizes the fact that, if racial interests are to be considered impartially, the native's natural preference for his own kind should be given equal consideration with the similar preference for his own on the part of the foreigner. This is proportional representation. It is a declaration that what we now are racially that we propose to remain. As Commissioner Curran has well put it, each year's immigration is to be "an exact miniature of what we are as to stock." If there ever was a sound, fair, bedrock immigration policy, this is surely such a policy. The act of 1924 is designed to keep our country from becoming any more of a "polyglot boarding-house," as Theodore Roosevelt aptly phrased it, than it already is; to maintain, as nearly as possible, our present racial *status quo;* to preserve, as best we can at this late date, something approaching racial homogeneity. Are these objects "unfair," "discriminatory," "un-American"?[1]

Certain groups opposed to restriction are insisting that this new law of 1924 was a hurried piece of temporary legislation; rushed through without adequate consideration; not representative of public opinion. Nothing could be farther from the truth. It was the outcome of a steady growth of restriction sentiment, as is abundantly evidenced by the literature on immigration during the past twenty to thirty years; by the enactment of the successive laws of 1882, 1885, 1891, 1903, 1917 and 1921; and by the report of the U. S. Immigration Commission, completed in 1910. This report, fifteen years ago, recommended restriction "as demanded by eco-

[1] Beginning with July 1, 1927, the total new quota immigration is to be 150,000 a year. The annual quota of any nationality is to be "a number which bears the same ratio to 150,000 as the number of inhabitants in continental United States in 1920 having that national origin bears to the number of inhabitants in continental United States in 1920." This is the "racial origins" provision and was suggested by Senator David A. Reed, of Pennsylvania. It cuts straight through, and ends, the controversy as to whether the quotas shall be based on the census of 1910 or on that of 1890. The quotas are no longer to be based, as now, upon the *foreign-born,* those composing the alien "colonies" and alien "blocs" now in this country, *ignoring the native-born,* but are to be divided among the different nationalities according to the national origins of our population as a whole.

This is an even fairer apportionment, if that be possible, than the one now in operation. It gives southern and eastern Europe essentially the same percentage of the total immigration as at present. On the "national origins" base, however, certain countries within each group will have their quotas changed somewhat, up or down, so as to conform, even more closely than is the case with the 1890 census base, to the representation in our present population of each stock derived from a given national origin.

nomic, moral and social conditions," and also suggested a percentage limitation. No immigration measure ever had such deliberate and intelligent consideration as was given to the new act. The overwhelming majorities by which the bill passed Congress clearly reflected public opinion. The present immigration law is not a temporary measure. It represents a permanent policy and was so accepted by the American people when passed. There is absolutely no necessity for any further investigation of immigration. Few national problems have been so completely "investigated" during the last two or three decades. There are few on which information is more complete. The limitation of immigration by means of a quota is settled American policy. The organized opposition of certain racial groups to the present law will simply confirm the American people in their belief that the act of 1924 is sound policy, and will again emphasize the fact that we have in our midst considerable numbers of un-Americanized aliens who are loyal to their own race and traditions rather than to the United States and its institutions.

The new law has successfully accomplished its two main objects. It has reduced the quantity of legally admissible new immigration to about one half of what it was under the preceding law. The non-quota contingent, which comprises aliens from the western hemisphere, relatives of aliens already in the United States, and other exempt groups, will amount to at least as many more. Taking both quota and non-quota together, immigration now averages about 1,000 a day. This is roughly about a third of the pre-war numbers. Secondly, distribution among the various nationalities is now fairly in accordance with the racial composition of our present population. This is a logical allotment, safe for us and fair to all.

Standing guard at Ellis Island, the gate through which most of our immigrants enter, Commissioner Curran has the best opportunity in the country of observing the effects of the new law. He says:

> As an affirmative performance, the immigration act of 1924 has already done great good to our country, and it gives promise of doing more. The immigrants who come to us now are fewer and better. They are cleaner nowadays. They possess better health, better intelligence, better promise of industry that produces, than did their predecessors. In the main they are outdoor folk, pink-cheeked, long of limb and muscular. They will labor rather than barter, work in the open rather than buy and sell in the alleys. They are self-contained, confident. And they are young. It is the youth of Europe that is coming through the island these days.

There is another very important point, long emphasized by those who have advocated numerical limitation and selection of immigration. By reducing our annual immigration and by increasing the proportion of immigrants from northern and western Europe, our

problems of education and assimilation are inevitably greatly simplified. We have breathing-space. We can begin to make some headway in our stupendous task of amalgamating and "Americanizing" our foreign-born. No more striking testimony on this point can be found than the statements of Mr. Bradley Buell, secretary of the New York City Council on Immigrant Education, as reported in the New York *Times*, July 17, 1924:

> By limiting the number of immigrants who will come in, the new immigration law gives organized education and social work its first real opportunity to help the foreigners already here to take a more intelligent part in the life of the city. . . . Ninety per cent. of the immigrants who have been coming here annually could neither speak, read nor write English when they came—and many live here for many years without acquiring a working knowledge of the language. Their contact with other races than their own is subject to the same kind of irritation that we have in Europe. The jealousies, traditions and prejudices of the old world have been transplanted here and will continue unless a common basis of language and ideals can be supplied by American leadership. The children learn English in the public schools, it is true, and often speak only imperfectly the language of the parents, but this frequently means that they become neither one thing nor the other—good American or good Italian, Pole or Greek—a factor entering into the high percentage of criminality among the children of foreign parents. To accomplish constructively the delayed task of assimilation is the opportunity now afforded.

(2) Selection

The new immigration act embodies the first attempt that the United States has ever made to conduct a preliminary selection abroad. Every intending immigrant must now have an "immigration visa" issued by a United States consular officer. Before obtaining this certificate the alien must present considerable proof of his good character and worth. The evidence required includes certain important documents, such as birth certificate and penal record. In addition, the law requires the immigrant's statement that he does not belong to any of the various classes excluded from the United States by our laws. The consul has the right to refuse the visa if he "knows or has reason to believe that the immigrant is inadmissible."

This new plan is not in any sense of the words a medical or general "inspection" abroad, but it is, as it was intended to be, a preliminary "weeding out" overseas. There can be no doubt that the plan is working out satisfactorily, in spite of the many cases of dishonesty and perjury among the aliens who apply for the visas. Hon. Albert Johnson, chairman of the Committee on Immigration of the House of Representatives, has said (Feb. 11, 1925), "the quality is grading up noticeably, due principally to the overseas questionnaire." While far more might be done in the careful selec-

tion of our immigrants before they embark, there is no doubt whatever that this new law has taken a distinct step in the right direction.

(3) Humanitarian Provisions

The act of 1924 goes far beyond any preceding immigration law in the provisions which it makes to diminish the hardships which our immigrants used to suffer. The preliminary selection abroad prevents the embarkation of a considerable number of aliens who would be found inadmissible on their arrival here. Further, under the former law (1921) many aliens arrived here after the quotas for their various nationalities were full. Merely because their ship was slower than some other vessel, through no fault of their own, thousands of aliens were debarred as "excess-quota" and deported. The new law has ended this unhappy situation. The immigration visas are issued only up to the numbers allowed by the quota, and are good for four months. Therefore, if an alien comes at any time within that period he can not be denied admission as being in excess of the quota. Again, the visas issued in any month may not exceed 10 per cent. of the annual quotas. This provision stops the rush of aliens at the beginning of each month and at the end of the year; and does away with the discomforts due to excessive congestion at Ellis Island. Furthermore, the number of rejections of aliens inadmissible under our laws has been decreasing, as the consuls have learned their duties and have been more careful about granting visas.

As to the admission of families: Wives and unmarried children under 18 of citizens of the United States are admitted without quota limitation, and in issuing visas preference up to 50 per cent. of the annual quota of any nationality is given to aliens who are unmarried children under 21, fathers, mothers, husbands or wives of citizens. The law thus makes reasonable provision for keeping families together. Furthermore, it should be remembered that aliens still overseas who wish to join relatives in the United States and do not fall within the non-quota or preference groups can still come in under the regular quotas, if otherwise admissible. In addition, the law makes specific provision for the non-quota admission of ministers and professors, with their wives and unmarried minor children; of bona-fide students, tourists, those coming temporarily for business reasons, and others.

In spite of the many humanitarian provisions in the new immigration law, stories of alleged hardships are constantly finding their way into the newspapers. There are reports of exclusions of individual aliens who came with consular visas and expected to be ad-

mitted for that reason, and there are pathetic stories of separated families. Most of these stories are circulated, for propaganda purposes, by organizations and individuals who are seeking to stimulate opposition to the law in order that it may be modified. It is always easy to arouse public sympathy in cases of supposed individual hardship, especially when these are presented in the lurid fashion of many of our yellow journals. Hundreds of such reported cases of hardship have been investigated by the officials of the Immigration Service, who found that there was little or no truth in them.

Again, it can not too often be reiterated that the immigrants know our immigration laws far better than we do. When the consular visa is applied for, the alien has to answer a very full questionnaire in which he is thoroughly informed regarding the causes for which he is liable to exclusion. It is safe to say that in most cases an alien excluded on arrival here knew when he received his visa that he, or the member of his family who is excluded, was likely to meet this fate. He has no grounds for complaint against the law or the United States. He knew that an immigration visa is not a ticket of admission, for he was definitely told so when he appeared before our consul abroad.

Further, in spite of the provisions for the non-quota admission of certain immediate members of the families of citizens and the preference allowed within the quotas for other members of the families of citizens, "sob-stuff" stories of separated families flood our papers. An alien now in this country wants to bring in all his European relatives and this may be impossible under the quotas. Some hyphenated organization composed of fellow-countrymen of this alien immediately takes up the case, dresses it up in a sensational and heart-rending fashion, and a yellow journal reporter writes up the story for the front page of his paper. But before becoming excited about such cases, we should remember that the United States did not separate that family. It was the family which separated itself, in Europe, when one or more of its members first came to this country. There is a widespread campaign, well organized and well financed, to have the law modified so that more distant relatives than those already provided for shall be admitted. To take such a step would break down the law completely. Everyone in Europe and near-Asia is a near relative or at least a "cousin" of someone already in the United States. If we started to lower the bars to all such relatives there would be an endless chain of quota-exempt persons. Obviously, under the present law, even the relatives now admissible, either non-quota or by preference within the quotas, can not all come here this year, perhaps, or even next year.

But it is not unfair to let them wait their turn. When we wish to travel on a limited train and can not secure accommodations, we wait for a later train. This whole situation has been clearly stated by Hon. Albert Johnson as follows:

> In the meantime it may be said that the law puts no obstacle in the way of emigration. If an alien wants to unite with his family, there is nothing to prevent such union in the country from which he came. No alien comes here except by his own initiative. Our government does not separate any alien from his family. His coming and his separation from family always are voluntary on his part, and in most cases with full knowledge of the probable difficulties. It follows that we are under no obligation to conform our governmental policies to his desires or alter our statutes to suit his convenience.

Americans must be careful not to be carried off their feet by the many pathetic tales of the "injustice" and the "cruel hardships" supposedly inflicted by our immigration law. As Mrs. Nathaniel Thayer, of the Division of Americanization of the Massachusetts State Department of Education, has so effectively expressed it, "Let your heart ache for suffering humanity, but let it beat for the United States."

(4) Additional Legislation Needed

While it is still too early in our experience with the new law to specify all the amendments which may later prove to be desirable, one thing is already certain. Registration of all aliens must be required. With the increasing restrictions which have been put upon immigration, the smuggling and surreptitious entry of aliens across our land borders and by sea have enormously increased. While most of these "bootleg" immigrants are probably mentally and physically up to the very low standards which we have set, many doubtless belong to the diseased and defective classes who should most rigidly be excluded. Secretary of Labor Davis advocates registration as an effective way of outwitting the border-jumper and the smuggled alien. Under this plan every alien would be required to register or enroll annually. Failure to register would be punishable by a fine. Registration would be carried out under the auspices of the Department of Labor. A final check-up of aliens who failed to comply with the law would naturally occur when an alien applied for his citizenship papers.

Aliens legally admitted to the United States under the (1924) law must surrender to the government all the papers they bring with them, such as passport, birth certificate, etc. Further, inasmuch as the law now places upon the alien the burden of proof as to his right to be here, he should surely have the evidence of this right which a preliminary registration on landing would give him.

Such registration would in fact be a receipt for the papers which he surrendered on his admission—a legitimate and obvious protection to him throughout the time until he becomes an American citizen. This plan would not only help in the work of assimilation and education and as an important step towards naturalization, but, what is of even more importance, it would reveal the presence of criminals, diseased, defective and other illegal entrants. If our laws against undesirable immigration are to be effective, registration of all aliens is a necessity. Again, by bringing the newly arrived alien regularly into contact with our government authorities, in the process of annual registration, we should be protecting him against those of his own nationality, already here, who are always ready to take advantage of his ignorance to exploit him for their own gain. Registration would thus be a simple act of Christian charity on our part. The requirements of registration would greatly simplify the process of Americanization and naturalization. There is no hardship or indignity in this for any alien who is rightly here. In registering aliens in the United States we should merely be doing what Great Britain, France and other liberal nations in Europe have found to be necessary for their own protection. Not to do everything in our power to fight illegal entry is to be unfair to those who, respecting our laws, patiently await their turn to come in under the legal quotas. Registration is advocated by the New York Chamber of Commerce, by the Committee on Immigration of the Eugenics Society of the United States, and by many other important bodies. Police Commissioner Enright, of New York, is on record as believing that every citizen as well as every alien in New York should be forced to carry a card containing his photograph and finger-prints, in order that criminals and other undesirable persons may the more surely and speedily be apprehended.

The successful operation of the new consular immigration visas, so far as these go, suggests a more thorough overseas investigation of intending immigrants before the visas are granted. In the development of this plan care must be taken not to conflict with treaty provisions limiting the jurisdiction of our consulates, and in any event final inspection at the point of entry into the United States must be retained. This will be necessary to guard against the danger of fraud and maladministration which may occur abroad, and also to detect cases of inadmissibility which develop, or first appear, between the time of inspection abroad and the arrival of the immigrant in the United States. Between the presentation of the alien's passport and the granting of the visa, the American consul could, if his government instructs him so to do, ask for a good deal more

information concerning the intending immigrant than is now called for. This information might well cover medical certificates regarding physical and mental qualifications and even evidence as to pedigree or family-stock value. The American consul would *demand* nothing. He would simply require, as a prerequisite to viséing the passport, that adequate information must be had. If the government of the alien's home country did not cooperate, nothing would be done; the passport would not be given a visa; and the emigrant could not land in America. Thus, automatically, the alien's home government, by refusing to cooperate in the emigration requirements of one of its own citizens to whom it had already given a passport, would reduce its own immigration quota to zero. This would seem a fair proposition on the part of the United States.

In conclusion, the immigration act of 1924 is sound American policy. It expressed the conviction of the American people that "immigration is a long-time investment in family stocks rather than a short-time investment in productive labor." The law is working remarkably smoothly. By giving the different nationalities of immigrants roughly the same proportions of the total quota as these nationalities bear to our total population there is a fair, impartial allotment. In this allotment we recognize the fact that the different nationalities in our country have a natural prejudice in favor of admission of people of their own kind, but we maintain that it is only right for the native-born American to have the same preference in favor of his own stock, and that the only way to treat all alike is to have the proportional representation of all racial groups in our annual immigration, which the act of 1924 assures. This new law, therefore, should be maintained and further strengthened in such respects as experience in its operation shall indicate to be necessary for the fulfillment of its fundamental purposes.

THE FUTURE PROGRESS OF MEDICINE

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It appears particularly appropriate, I believe, to speak of the progress of medicine in this hospital where for many years the clinical divisions and the laboratories have worked together for the greatest benefit of the patients and also for the advancement of medical knowledge, that is, for the good of the future patients. We must always realize that the only purpose of medicine is to decrease human suffering by preventing disease or curing it. But this end can not be reached except through a scientific understanding of the functions of the organism when they are modified by pathogenic factors.

To-day, medicine consists of an immense quantity of observations, partly empirical and partly classified according to scientific method. It is a science in the making. While the treatment of certain diseases, for instance, the disturbances of the pancreas and the thyroid gland, is thoroughly scientific, the handling of others, such as mental diseases, is still entirely empirical. It is obvious that the progress of medicine is bound to the development of the sciences concerned with living matter and living organisms. These sciences, which deal with intricate physico-chemical phenomena and meet with immense technical difficulties, have advanced much more slowly than those which concern themselves with non-living matter and occupy a lower rank in the hierarchy of knowledge. Physiology, which was in its infancy when physics and chemistry were widely developed, can not as yet supply to medicine in every part of its field the information necessary for the scientific study of its problems. As the physician must help patients afflicted with all kinds of disease, he can not always remain in the territory which has been scientifically explored. Therefore, his task is very much more difficult than that of the physiologist who can select his problem, reduce it to its simpler terms and solve it by techniques accurately adapted to the subject of the experiments. On the contrary, the physician must wander through the entire field of medicine and often meet with diseases due to unknown causes and developing within an organism of unknown resistance. He is helped by his scientific knowledge as far as it goes. But when he has reached its limit, he has to guess. The great clinician must possess the intuitive power of the man of genius.

The past fifty years have been a period of triumph for medicine because the revelation by Pasteur of the rôle of microorganisms in disease has led to the creation of bacteriology and immunology. These sciences have brought about in a spectacular way the conquest of infectious diseases, a fact of momentous importance to humanity. The death-rate of the population of civilized countries has been decreased by better hygiene and efficient protection against cholera, plague, yellow fever, and also typhoid, tuberculosis, etc. Not only has preventive medicine determined an increase in the quantity of human beings, but it has allowed profound modifications in their mode of living. Men are crowded into large cities and into factories where they work as part of the machines, without danger of great epidemics and without seriously impairing their health. Immense armies, which heretofore would have been rapidly reduced in size by infectious diseases, are kept in the field for years without large spontaneous losses. The admirable work of Gorgas in Panama has opened a new era in the history of mankind. Life in the tropical climates has been rendered possible for the white man, who has thus acquired the power to dominate the entire world. While the ultimate significance of Pasteur's discoveries can not be foreseen, it is certain that medicine, in protecting men from infectious diseases, has already accomplished miraculous progress.

But we may doubt whether this victory has so far brought much happiness to the world. Has it greatly modified the position of the average man as regards disease and death? Probably not. Although the adult individual has much fewer chances of dying from smallpox, cholera, tuberculosis or typhoid fever than fifty years ago, his expectation of reaching the age of seventy-five or eighty has not markedly increased. But he surely has more prospect of being tortured by some form of cancer, afflicted with slow diseases of the kidneys, the circulatory apparatus, the endocrine glands, of becoming insane, suffering from nervous diseases, or of making himself miserable by his lack of judgment and his vices. Modern medicine protects him against infections which kill rapidly, but leaves him exposed to the slower and more cruel diseases and to brain deterioration.

There is no great hope of immediate improvement in this situation, in spite of the remarkable advances which have been made recently in physiology by the discovery of the active principles secreted by endocrine glands, by the building up of the science of nutrition and by a better conception of respiration, of metabolism, of the acid-base equilibrium of the blood, etc. Although great

progress has been accomplished in the treatment of diabetes and of the disturbances of the thyroid gland, it is far from possible to cure these diseases or prevent their occurrence, as we are still absolutely ignorant of their causation. The insufficiency of medicine is more flagrant when it deals with tumors. What are the determining factors of cancer? What is its nature? What are the causes that render the human organism susceptible to malignant tumors? No one to-day can give a scientific answer to these questions. We do not know what brings about arterial hypertension. Our ignorance of the causes of chronic nephritis and of most of the diseases of the circulatory apparatus is practically complete. It is neither possible to cure nor to prevent them. Our lack of knowledge is still greater in the field of the nervous and chiefly of the mental diseases, whose nature remains almost as mysterious as it was during the Middle Ages.

It is clear that the future progress of medicine must consist in finding the nature and causation of some of these diseases and their prevention. Medicine should attempt to lead men to extreme old age without suffering, and also to increase their moral and intellectual value, because the quality of the individuals is far more important than their quantity for the happiness and progress of the community. To expect this from medicine does not appear to be asking the impossible when we consider what has already been accomplished. If our civilization does not crumble, and if scientific research goes on at increased speed, we can reasonably believe that our expectations will be fulfilled. The scientifically organized hospitals, the large medical clinics and their multiple laboratories, the institutes for medical research in this country and in Europe, by merely continuing the investigations in which they are at present engaged, will, without any doubt, immensely advance our knowledge of the nature and mechanism of disease. But fundamental principles have to be discovered; entirely new fields must be opened, and this can be accomplished only by pure science.

Science, when connected with medical research, does not go far enough from the beaten road, and is often handicapped by its attempts to make useful discoveries. On the contrary, pure science has no immediate practical purpose. Its object is merely to find the truth and to understand the universe. It does not attempt to make discoveries which could be applied to industry or medicine, but seeks an accurate conception of the world in which we live and of our relations to it. Pure science classifies the empirical knowledge of nature that we already possess. Beyond the apparent and often puzzling complexity of phenomena, it detects the common

element which underlies their seeming diversity. Then it can draw the generalizations which we call laws and predict and reproduce the phenomena at will. The understanding of nature always has led to its control. Pure science which seeks knowledge in an absolutely disinterested way becomes, almost in spite of itself, the great power of this world. There is no other manner of obtaining a thorough knowledge of nature and of mastering it.

If physiology were studied as a pure science far from hospitals and medical schools, by men possessing the creative imagination and the spirit of the discoverers of the fundamental principles of physics and chemistry, the secrets of the functions of the body that we still lack would be brought to light. These discoveries would indirectly lead the physician to understand the nature of the diseases of the organs whose functions are incompletely known to-day and to prevent them. This institute of pure science, where physiologists, physicists and chemists could devote themselves to the investigation of fundamental problems, would also create the proper conditions for the building up of the science which will occupy the summit of the hierarchy of human knowledge, the science of thinking matter and energy.

The development of this new psychology is our only hope of improving the quality of human beings. But it will be an immense task, because the structure of the central nervous system, as unveiled by Ramon y Cajal, is of infinite complexity. It is probable that the discoveries which will open this field to scientific investigation will be made on the frontier of physiology and physics, and will require the development of entirely new methods by some man of genius. Modern psychology, in spite of its progress, will have the same relation to this supreme science as alchemy to the chemistry of our day. Our knowledge of cerebral physiology is in the embryonic stage. We are still entirely ignorant of the properties of nerve cells, the nature of nervous energy and the significance of telepathic phenomena. No one suspects the manner in which memory, intelligence, courage, judgment and imagination are connected with the brain cells. The possible affinity of certain structures of the brain for some chemical substances secreted by endocrine glands and other tissues has never been studied. While courage may be caused by the effect of the sex glands on the cerebral cells, and may not be due to a property inherent in those cells, creative imagination, judgment and other qualities possibly require for their development the action on the nervous system of substances produced in other parts of the body, or possibly introduced into the organism with the food. The knowledge of the conditions that permit the

evolution of judgment, imagination, kindness or courage in a race, family or individual, or of the conditions that bring about the disappearance of these qualities, would give the human race far more happiness than the complete eradication of plague, cholera and typhus from the earth. At the same time, the discovery of some of the fundamental properties of nerve tissue would enable medicine to prevent many of the nervous and mental diseases.

It is obvious that the functions of the brain must be better understood in order that, without intellectual or moral deterioration, the human race may stand the new conditions of life imposed on the individual by modern civilization. The spiritual progress of man could be greatly promoted by a scientific knowledge of the physicochemical phenomena which take place within the brain cells. Instead of merely increasing the number of human beings, we could increase their quality. The progress of medicine, understood in this manner, would be the most important factor in the development of civilization. As Descartes wrote three hundred years ago, we must ask from medicine the solution of the problems which are vital to the greatness and happiness of the human race—"c'est à la médecine qu'il faut demander la solution des problèmes qui intéressent le plus la grandeur et le bonheur de l'humanité."

THE PHYSICAL BASIS OF DISEASE

By THE RESEARCH WORKER

STANFORD UNIVERSITY

XII. MEDICINE OF THE FUTURE (*Continued*)

9

"Say! Youse guys'll hav't'git out o' here!" shouted the cameraman. "Got to use this f'r location."

The hormonologist shifted to air-transmission. The henry rose around me, leaving me standing on the lawn with the movie director.

"Moron Educational Filums, Ink," he explained. "Medical dope. 'Charlie and Streptie.' Allegory. We've just learnt how to put this stuff acrost. . . . Now Charlie. Some pep. Ready? Let'er go! . . . Camera!!"

With twirling cane the dearly beloved Charlie shuffled on. Tripped. Regained his balance. Turned sidewise to the camera. Stooped to pick a flower. Thus revealing a string of giant beads attached to his familiar nether garment.

"D'ju get it?" asked the director. "Streptie already attached. Charlie nonchalant. Allegory. Latent period."

A foot-long, glistening stingeree at the end of the string of beads twitched impatiently ("D'ju get it? Streptie's dick-dick. Allegory. Toxin. . . . All right, Charlis. Shove 'er out").

The string of beads, nourished by the life-blood of Charlie's garment, rapidly elongated. Writhed and squirmed. Impatiently darted its deadly dick-dick. Now to Charlie's knee ("D'ju get it? Allegory. Rheumatism"). Now to Charlie's heart ("D'ju get it? Allegory. Endocarditis"). Ever returning to Charlie's mouth ("D'ju get it? Allegory. Commonest portal of entry").

Charlie struggled with the fast encircling beads. Terrified by the flickering dick-dick. Fell fighting to the ground. The deadly dick-dick raised for the knock-out ("All ready, Doug").

The beloved athlete, chicken wings on heels ("D'ju get it? Classical touch"). Obstetrical forceps shield-like over left arm ("D'ju get it? Sex appeal"). Burnished his four-foot hypodermic ("D'ju get it? Science"). Glanced at the safety net. Tail-spinned down the wire to Charlie, now contorting in death agonies. Plunged his giant hypodermic through Charlie's body. Till the needle protruded a foot from Charlie's back. Squirted liquid fire on the deadly stingaree ("D'ju get it? Kills the dick. Allegory. Antitoxin").

The string of beads writhed in agony. Broke in two near Charlie's garment. Registered helplessness. Slunk away to its lair. A dozen loose beads rolled to the ground ("D'ju get it? Allegory. Infection of environment. Close-up later"). One bead only remaining, attached to Charlie's unmentionables ("D'ju get it? Streptie's head. Jaws locked in Charlie's pants. Allegory. Human carrier").

The dearly beloved collie capered on. Unnoticed by Doug, who was trying his durndest to register benevolence. The collie rolled on the grass. Dashed off toward a group of children. Several beads adhering to his hair ("D'ju get it? Allegory. Animal carrier").

Charlie raised eloquent hands to Doug. Doug shook his head. Pointed upward to Mary's perennial curls. Crowned with a glistening 1850-type binocular microscope (" 'Honor not me; but the Spirit of Science, my Guide, my Inspiration.' Hot stuff! Cut!!").

"Nine o'clock to-morrow, folks. Streptie and Steeple-Jack Jim."

And, the henry again under me, I was speeding with the hormonologist toward a distant group of buildings.

10

The henry plunged through a plate glass-window. And I breathed the blended incense of balsam and bull durham, familiar atmosphere of the histological stock room. I looked around. Dark-green walls, mahogany-colored furniture, dull-black table tops, dark brownish-green floors, cream-colored ceiling, ground-glass skylight, windows well above the level of the eye.

"Looks like the specifications for a histological laboratory I once prepared," I said. "Turned down by the university architect."

"Modern cytology," said the eminent histologist in whose research room I was sitting, "dates from the invention of the ultramicroscope. This did for cytology what the compound microscope did for gross anatomy in your day."

"The ultramicroscope," he continued, "was the outcome of the discovery of a method for light amplification. A mechanic in one of the Hollywood studios. Was first applied to night photography. Finally adapted to optical instruments.

"Its first use in cytology was in the study of protozoa. Many details revealed by faint, oblique, multiple illumination, obscured by the intense transverse illumination of your day. Ultraviolet rays were finally adapted for the initial luminant. For routine work we use a magnification of a hundred thousand diameters."

"Our greatest difficulty," he added, "was in preparing the extremely thin tissue sections necessary for these magnifications. This we finally did by ———"

And I found myself back in the henry, still speeding with the hormonologist toward the distant group of buildings.

11

"What happened?" I asked.

"Cigarette hit the windshield," he explained. "Dropped from upper ———"

And I was struggling in the grasp of something I could not identify. With a mighty effort I freed myself. Threw out my hands. Caught hold of the back of the front pew.

"There has arisen in this day," intoned the Rabbi, "a group of skeptics, who would explain away Tamalpias as a natural phenomenon, a blending of mob-psychology and geomutans, even suggesting borings in that Sacred Mount. Who are they, ultramicroscopic worms, to question the instrument through which Omnipotent Bio-Rationality make His revelation!"

"After Tamalpias," continued the curate in whose library I was now sitting, "physical or bodily evolution was the universal teaching of the church. Many ancient manuscripts were eventually brought to light. Among them, the Vatican Manuscript, in archaic Arabic, and the Babylonian Manuscript, in cuneiform. Both give accounts of man's creation antedating the oldest manuscript incorporated in Genesis, by at least two thousand years. In 2135, translations of these two manuscripts were added to the Bible. They are the basis for our present interpretation of Genesis. Here they are, Pregenesis Legends, Babylonian Manuscript, First Scroll:

> 12. IN THE SIXTH DURATION, GOD MATERIALIZED ON EARTH, AND KNEW OHN, FAIREST VIRGIN OF THE SIMIIDAE, AND TO THEM WAS BORN AH-OM.

And here, after describing Ahom's ostracism by the Simiidae:

> 21. AND GOD TOOK COMPASSION ON AHOM, AND LAY WITH MOE, VIRGIN OF AHOM'S CLAN, AND TO THEM WAS BORN AH-OV.

12

"The ultramicroscope must have revolutionized histology," I said to the hormonologist, as I regained my balance in the henry.

"The cell, of course, is no longer regarded as the biological unit of life," he replied. "Our unit is the biophore, or bion. Fixed and wandering intracellular units. Various types. Various struc-

tures. Various functions. Uniting and cooperating to form the cell. About the same way cells are united and coordinated to form the body."

"A remarkable development of intracellular histology since your time," he continued. "And of intracellular physiology. Contractile bions. Conducting bions. Digestive bions. Bion mitosis. Amitosis. Bional conjugation. Bional distribution in the blastoderm. Interbional hormones. Extra-cellular or free bions. Comparative bionology. Why! These terms must be new to you! Bional hyperplasia. Metaplasia. Bional atrophy. Bional regeneration. Bional senility. Bional crises. Differential bion-counts. Bional symbiosis. Bional parasitism. Pathogenic bions. Bion infections. Antibion therapy. Bional ——"

"Yes," I interrupted, I fear somewhat impatiently. "And a thousand years from now some one will kick your bion to pieces. And biology will revolve about an ultra-on."

"Possibly. Probably. But not the histologist. It may come from the chemical laboratory. Chemists are already approaching it. With their self-synthesizing colloids."

"You will be imagining self-propagating pathogenic molecules next," I said.

"Why not?" he replied. "A single foreign self-synthesizing molecule might conceivably cause death."

"Shades of Novy!" I said.

"And then what becomes of your theology!" I added. "Unbroken chain from self-synthesizing molecules to man, the highest self-synthesizing colloid."

"With the development of cytology there has been an intensification of religious belief. Not one fact has been discovered, nor can ever be discovered, contrary to our present religious conceptions. The Unknowable of your time has been multiplied to the ten-thousand-fold Mystery of to-day. The Omnipotent Purpose, that is above all and within all. That breathed life-potentiality into the colloid molecule. That coordinated a thousand molecules to the bion. That harmonized ten thousand bions to the cell. That differentiated, and blended ten million cells to the animal body. That breathed the dawn of Rationality into the bodies of the Simiidae. Herald of the day of human coordination in tribes and nations. And of the ultimate, inevitable world coordination, world-cooperation. Perhaps beyond. Do you wonder that a renowned biologist now sits on the Throne of St. Peter! A great biochemist at Westminster!"

"Children's Ward," he explained, as the henry circled an outlying group of buildings.

13

And I found myself, greatly reduced in size, sitting with other six-year-olds, on the lawn, grouped about the hormonologist, who meanwhile had grown a long Santa Claus beard.

"And did they do what Peter said?" asked Billie on my right.

"No, indeed," answered Santa. "Why! The very next day! When Peter was away. Away up in the clouds. Exercising his Flamingo. They went down Nevergo Lane. Wendy. And John. And Michael. Down the Forbidden Lane. And they came to Peter's sign:

ITCHY-ITCHY GLEN
TresPassgers
Will be ProsTicuted!

"Did that stop them? No, indeed! They went right on. Past Peter's sign. And came to Peter's fence.

" 'It isn't a very strong fence,' said Wendy.

" 'It isn't a very high fence,' said John.

" 'Wigg'y fence,' said Michael.

"Then Wendy saw some flowers. On the other side of the fence. In Itchy-Itchy Glen. Beautiful flowers. And John saw some butterflies. On the other side of the fence. In Itchy-Itchy Glen. Beautiful butterflies. And Michael saw some birds. Beautiful birds. Red. And yellow. And blue. An'———"

"And purple!" interrupted Georgie on my left.

"And green!" added Billie on my right.

"And purple. And green," agreed Santa. "And spotted. Golden spots. And Wendy crawled through the fence. The way big girls always do. And ran to pick the flowers. And John climbed over the fence. The way big boys always do. And ran after the butterflies. And Michael crawled under the fence. The way little boys always do. And ran after the birds.

"Then Wendy began to itch. And John began to itch. And Michael began to itch."

"He! He!" giggled Georgie on my left.

"He! He!" echoed Billie on my right.

"It was no laughing matter," said Santa, very sternly. "These were terrible itches. Terrible. First Wendy itched. Then John itched. Then they all itched together."

"Ugh!" squirmed Georgie on my left.

"Ugh!" wriggled Billie on my right.

"Then Wendy began to scratch. And John began to scratch. And Michael began to scratch. Then they all scratched together. They scratched their arms. They scratched their legs. They scratched their backs. It was worst on their backs. Right in the middle. Where they couldn't quite reach."

"Ugh!" said Georgie on my left.

"Ugh!" echoed Billie on my right.

"Then they rolled on the ground. The way Nana does. When she has itches. First Wendy rolled. Then John rolled. Then Michael rolled. Then they all rolled together.

" 'If Nana were only here,' said Wendy. 'She'd know what to do.'

" 'She always does,' said John. 'She'd know what to do.'

" 'Always does,' said Michael.

"And then they heard Nana's bark. Nana's worried bark. Nana's very worried bark. And Nana came. Bounding over the fence. Into Itchy-Itchy Glen. Nana wasn't afraid of Itchy-Itchy Glen. No, indeed! Nana was magic. She had often chased rabbits in Itchy-Itchy Glen.

"First Nana rubbed against Wendy. And looked up at Wendy. And whined. Then Nana rubbed against John. And looked up at John. And whined. And barked. And whined.

" 'That's her unhappy bark,' said Wendy. 'Her very unhappy bark. She's trying to tell us something.'

" 'If she could only talk,' said John.

" 'Only talk,' said Michael.

"Then Nana ran to a stone. A sharp stone. A very sharp stone. And hit her paw on the stone. Hit it hard. Very hard. And looked at her paw. And whined. And hit her paw again. And shook her head. And whined. And whined. And whined.

" 'That's her discouraged bark,' said Wendy. 'Her very discouraged bark. She's trying to do something. She just can't do it.'

" 'Trying to do some magic,' said John. 'Just can't do it.'

" 'Can't do it,' said Michael.

"Then Nana threw up her head. And howled. Her biggest howl. Her very far howl. And howled. And howled. And howled.

" 'That's her Peter bark,' said Wendy. 'Her very Peter bark.'

" 'She's calling Peter,' said John.

" 'Calling Peter,' said Michael.

"Then Peter came. On his Flamingo. Standing up. Driving with ribbons. And Peter jumped off. Right into Itchy-Itchy Glen. Peter wasn't afraid of Itchy-Itchy Glen. No, indeed! Peter was magic. He had known all along what would happen to the children. If they went to Itchy-Itchy Glen. That was why he had put up his sign. And his fence.

"And Peter knew what to do. Yes, indeed! Peter knew all the magic. First Peter drew his sword. His magic sword. The sword

with which he had fought the Pirates. Then Peter held the sword out. Held the sword toward Nana. The very pricky tip of the sword toward Nana.

"Then Nana barked. Her happy bark. Her very happy bark. And Nana jumped up. And hit her paw on Peter's sword. On the very tip of the sword. On the very pricky tip of the sword. And blood came!"

"Ouch!" said Georgie on my left.

"Ouch!" echoed Billie on my right.

"Then Nana put a drop of her magic blood on Michael. Michael first. Because he was the littlest. And the itches flew away from Michael. Flew up in the air. Forty-'leven billions of them. Just like dust. And the wind blew the itch dust away. Pu-u-ff! Just like that. Away from Michael.

" 'You can't see itches,' said Peter. 'They're so tiny. So very, very tiny. Only when you have a whole bunch of them.'

" 'Just like mama's talcum,' said Wendy.

" 'Taccum,' said Michael.

"Then Nana put a drop of her magic blood on Wendy. Wendy next. Because she was a girl. And Wendy's itches flew up. Just like dust. And blew away. Pu-u-ff!

"Then Nana put a drop of itchy-magic on John. John last. Because he was such a big boy. Almost a man. And away went John's itches. Forty-'leven billion of them. Just like that. Pu-u-ff!

" 'I'll never come to Itchy-Itchy Glen again,' said Wendy. 'Never, never, never again!'

" 'Never, never again!' said John.

" 'Never,' said Michael.

" 'Yes we will,' said Peter. 'We'll build a play-house here. A picnic house. And bring dough-nuts.'

" 'And ice-cream,' said Wendy.

" 'And apples,' said John.

" 'An' punking pie,' said Michael.

" 'And we'll change its name to Nana Glen!' said Peter. 'Itchy-Itchy Glen can't hurt you any more. No, sir-ee! Your magic now. Just like Nana. Nana's blood made you magic.'

" 'Then Wendy kissed Nana. Right on the nose. And John kissed Nana. On the ear. And Michael tried to kiss Nana. But Nana was so happy. She wouldn't hold still. She just jumped up and down. And wagged her tail. Wagged it 'most off. And barked. Her happy bark. Her very happy bark. You see Nana had known all along how to drive the itches away. Nana knew."

"Oh!" said Georgie on my left.

"Oh!" echoed Billie on my right.

"But what I wish to show you," said the hormonologist, as the henry settled to the driveway in front of the administration building, "are some of our diagnostic methods."

14

"Our most valuable diagnostic instrument," said the roentgenologist-in-chief, "is the ford-ray. This has done for non-osseous diagnosis what the X-ray did for bone diagnosis in your day."

"The method is based on the ford-phenomenon," he explained, "rectangular ultraradiation interference. Ford-rays intersected within the body by a perpendication sheet of ford-rays. An optical section is formed, at the plane of intersection. Visible by the light amplifier."

He held out an ocular.

And I saw the optical section of a pulsating heart. An assistant inserted a hypodermic into the patient. Portions of the pulsating heart-wall turned bluish.

"Vital staining," explained the roentgenologist. "Intracellular acidosis of the bundle of His."

Another patient. Optical section of the pyloric region. Hypodermic. Portions of the duodenal endothelism became luminescent. Two flickering stars in a neighboring lymph gland.

"Radium test. Beginning cancer. Two metastatic cells. Ninety-five per cent. probabilities of cure by immediate surgical removal. I suppose you had the beginnings of these tests in your day?"

"Vital staining and the topographical distribution of radium-salts were being studied," I replied. "But nothing had come of it."

Then I entered a darkened operating room. A black-gowned surgeon, ocular to eye. Moving small screws and levers on the end of a trocar, inserted through an uncut abdominal wall. Through a lateral ocular, an optical section of a pus cavity. Surrounding the appendix. Gradually the trocar point entered the cavity. Flowered into a set of tiny instruments. Which slowly moved as the screws and levers turned in the surgeon's hands. The appendix amputated. Sutured. The instruments and appendix fragments disappeared into the trocar.

The pus cavity gradually collapsed. Was dilated. Collapsed again. Finally expanded. The trocar withdrawn.

"Pus aspiration," explained the surgeon. "Followed by Dakin lavage. Final dilation with human antiserum. Plus streptosalvarsan. No necessity for hospitalization."

Another patient. Trocar in blood vessel of neck. Optical section of pulsating heart. Gradually the trocar tip entered the heart chamber. Flowered to a medley of clamps and hooks. Ruptured valve segments brought into opposition. Sutured.

"I wish Graham could see this," I said.

The henry rose to the passenger level and turned toward the emerald foothills of San Francisco Bay.

15

The dean's office, Burlingame Medical College.

"Founded in 1945," he explained, "by far-seeing business men. Union of the Stanford and California medical schools of your day. Now the medical Mecca of Western America. Only rivaled by our sister medical college in Seattle."

"I don't see how you crowd all your new subjects into a four-year medical curriculum," I said.

"Your old subjects, normal anatomy, normal histology, normal biochemistry, normal physiology and elementary bacteriology are required for admission," he answered. "Given in the preparatory college. Where they belong. These courses are also required of all secondary school teachers of biology and physiology. Of course, no student is competent to select medicine as his life-work till he's finished these subjects."

"Overcrowds the college course," I objected.

"Fully a year of your old college curriculum has been moved downward into preparatory schools, and grammar schools. Remember, your educational system was in reality adjusted to the capacity single-plus defectives. These are now shunted as rapidly as possible into trade schools, manual-training high schools, and other non-preparatory finishing schools. Also into non-preparatory junior colleges.

"Our medical curriculum opens with the two basal subjects, pathologic anatomy and histology and pathophysiology. Foundation for the early introduction of clinical work."

"Pathologic physiology!" I exclaimed. "Practically unknown as a teaching subject in my day. Why! I had an acquaintance who spent twenty years, impatiently marking time, waiting for a chance to develop just such a course in our medical schools.'

"The pivotal introductory course in our medical curriculum," he said.

"And the age of medical graduations?"

"M.D$_{B}$., with license as junior physician, about twenty-five. Promotion to M.D$_{A}$., with license as senior physician, about 30 to 31. Fordate, if won at all, usually 40 to 45."

And I found myself again in the henry with the hormonologist speeding toward the sister medical college in Seattle.

16

"How the Bay Region has grown," I said, as we reached the upper level.

"Following Tamalpias," he replied, "there was a phenomenal increase in real estate values in the old Mills Valley and San Raphael regions. An inflowing deluge of neurotics and hysteretics from Southern California. And from the east. Within two generations the region developed into the great Piedmont of to-day. With its three million inhabitants, palatial tourist hotels, magnificent churches and great theological seminaries. With their marvelous biological laboratories. Such a prominent feature of present-day theological education. Strange as it may seem, in place of Piedmont developing into a city of degenerates and incompetents as many predicted, it has become the great literary, artistic and musical center of Western America. As it has the world capital of protestant theology.

"Southern California, of course, suffered from this early piedmontophilia. Within ten years the Los Angeles district lost a quarter of a million people. A period of real estate slumps and business depression. Labor pains of the Los Angeles of to-day. Freed from its former incubus of neurotics, hysteretics and degenerates, the quiet, efficient substratum of keen intelligence in Los Angeles for the first time gained ascendency. Developed Los Angeles into the great intellectual center it is to-day. They now speak of this early period as 'The Years of Purification.' "

"What about research?" I asked.

The hormonologist threw over a lever. The henry swung to the south.

"Los Angeles Research University," he said. "Research Mecca of Western America. Mass production. Ph.D., or equivalent, required for admission. Administration building in Los Angeles. Circled by twenty suburban research institutes."

"And the conditions of work?" I asked

"Five year appointment as research fellow. Salary sufficient for modest luxury. Ph.FD., or equivalent, at the end of that time. Requirement for the fordate, the addition of one new fundamental pioneer fact. Pioneer fact, mind you. After three such facts, he is dedicated an Ace. The Research Acehood, the highest research honor."

"Aces!" I said. "Wonder how many medical Aces we had in my time. Respectable showing of fords. Starling, Smith, Banting, the Dicks. But, Aces?"

The hormonologist disappeared and I found myself standing on a lawn in front of a familiar looking building, its crumbling walls supported and reinforced.

"Old Astronomical Institute," explained a passerby. "Beloved shrine of the Research University. Nucleus around which the university developed."

17

"Of course," continued the curate to whose study I had mysteriously returned, "the Babylonian Legend is not the only legend of simiidaen rationalization. Other legends. Other simiidaean groups. Other parts of the world. But here's something that may interest you. Early segregation of man."

> 47. AND GOD LED THE SEED OF AHOM APART FROM THE SIMIIDAE, INTO THE VALLEY OF THE DHAN.

"This, also," he said.

> 69. AND AHOM'S SEED INCREASED A THOUSAND-FOLD IN THE VALLEY.
> 70. THEN SPAKE GOD TO THE PATRIARCHS:
> 71. "ALL OTHER VALLEYS GIVE I UNTO YOU, AND ALL HEIGHTS AND PLAINS, AND THE SEAS THEREOF."
> 72. "AND THE AHOMS WENT FORTH FROM THE VALLEY.

"Numerous other suggestive parallels," he added, turning the pages. "For example, Vatican Legend, First Scroll."

> 14. FOR SIX GENERATIONS, GOD DWELT AMONG THE AHOMS, AND COUNSELED THEM. ON THE SEVENTH, HE ASCENDED UNTO THE INVISIBLE MOUNTAINS.

"Basis for our present sabbatical system," he commented. "Every seventh year. Beginning with the nuptial sabbatical. All professions. All business. All trades. Except, of course, the pulpit."

"And the pulpit?" I asked.

"We preach only during Sabbatical Years," he said. "Twelve sermons. After six years of preparation and research."

"Daddy! Daddy!" said the five-year-old. "Stop writing! We're almost there."

* * * * * *

"You get off at Burlingame? Yas, suh. Ya-as, Su-uh! Thank y'suh."

"Mama! There's Aunt Linda and Uncle The'dore. See! In Henrioceffus latus."

"A-lo-ha oe, a-lo-ha oe," a diminuendo of student voices, as the train sped onward toward San Francisco.

THE END.

EFFECT OF SUNLIGHT ON GROWTH AND DEVELOPMENT

By Dr. W. T. BOVIE
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At the University of Maine, Orono, Maine, in the summer of 1924, a clutch of about two hundred and fifty chicks that were about one week old was placed in a greenhouse from which the plants had been removed.

They were divided into six groups, each group placed in a chicken wire cage. The chickens of the first group were allowed to run outside in the open sunlight, although they came into the greenhouse to sleep and eat. The other five groups were confined to the greenhouse throughout the experiment.

The chickens in the second and third groups were exposed to the rays of a quartz mercury vapor lamp for twenty minutes each day. The other chickens were shielded from this lamp.

The chickens in the fourth, fifth and sixth groups received only the sunlight which passed through the glass roof of the greenhouse.

All these chickens received a regular diet of chick grain, dry mash, sour milk and rock grit. Each group was supplied with water and a sand bath. The chickens in the third and fourth groups were given green food, consisting of chopped alfalfa and grass, in addition to their regular diet. The chickens in the sixth group had the regular diet with the addition of a small amount of codliver oil.

The treatment of the different groups is shown schematically in Fig. 1.

The influence of these kinds of treatment upon the growth and development of the chickens was observed and recorded every day.

At the end of the fourth week, the chickens in groups four and five which were exposed only to sunlight which had passed through the glass roof of the greenhouse did not appear to have as good an appetite, were less vigorous in scratching after their food and in their movement about the pens than the chickens of the other groups. The appetite of the chickens in group six which received codliver oil was below that of groups one, two and three. In other words, it was only the chickens in the groups one, two and three, *i.e.*, those receiving direct sunlight or those exposed to the light of the quartz mercury vapor lamp that were normal in every particular.

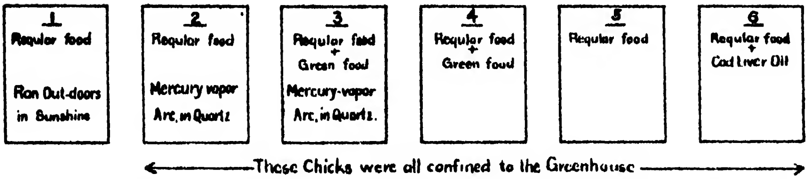

FIG. 1. Diagram showing the arrangement of cages and treatment of chickens in each cage.

All these differences were more marked by the end of the fifth week. At this time the chickens in groups four and five evidenced in marked degree the condition known to poultrymen as "weak legs." The legs appeared too weak for scratching or for support. The chickens remained in a squatting position most of the time, using their wings for additional support while moving about for food. They were unable to stand squarely on their feet and were obliged to assume the characteristic posture peculiar to this disease, with toes crossed and head held low in order to maintain equilibrium. Gradually, as this condition became more fully developed, the nails became long and curled, the bills soft and the plumage ruffled.

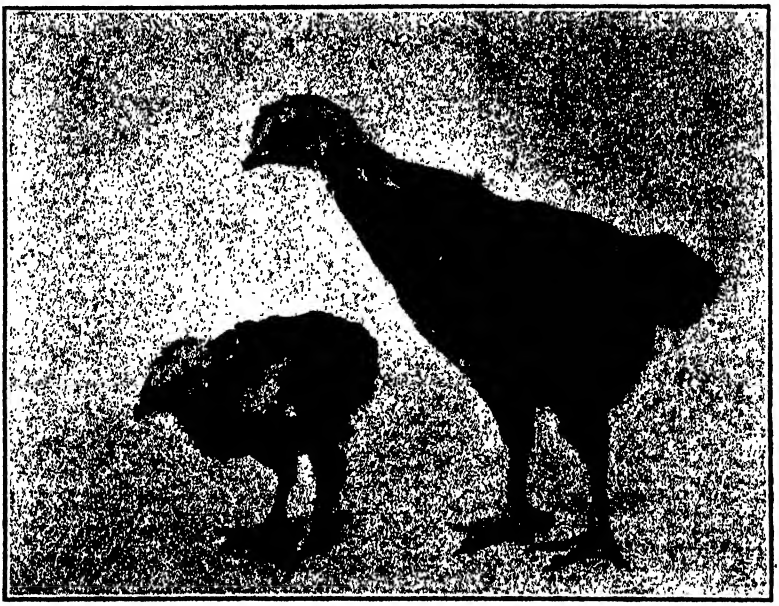

FIG. 2. The small chicken received only sunlight which had passed through the glass. The large chicken had been exposed twenty minutes a day to the light of a quartz mercury lamp. Otherwise it was confined to the glass greenhouse.

Fig. 2 shows very clearly the marked difference in size between the chicks which had received direct sunlight or had been exposed to the light from a quartz mercury lamp and those which had received only the sunlight which had passed through the glass roof of the greenhouse.

The larger chick shown is from group three, the smaller chick from group four. The smaller chick, while not showing the characteristic posture of "leg weakness," was the only one in the group which was able to stand while the photograph was being taken. This condition is also shown in a figure in a paper by Steenbock.

The difference in the rate of growth of the chickens in groups four and five and those in groups one, two and three is shown in the chart, Fig. 3.

The dotted line in this figure is a graph showing the total increase in weight of all the chickens in groups four and five. The continuous line is a graph of the total increase in weight of all the chickens in groups one, two and three. In this chart the number of days' growth is measured along the horizontal axis and the percentage increase in weight is measured vertically. The figure represents only the last thirty days of the experiment.

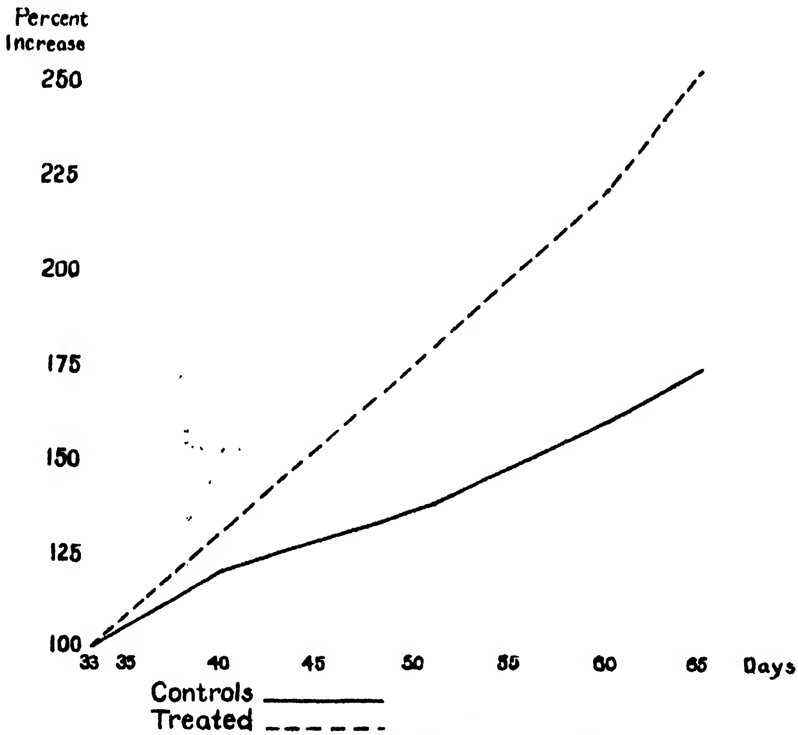

FIG. 3. A comparison of the rate of growth of chickens in groups 1, 2, and 3 with the growth of chickens in groups 4 and 5.

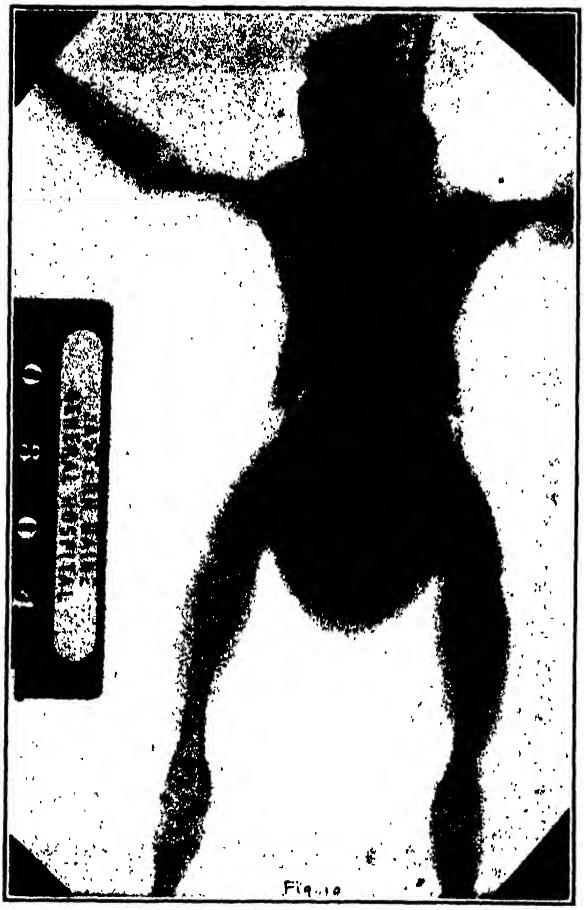

FIG. 4. X-ray photograph of the smaller chicken in Figure 2.

It will be seen that at the end of the sixty-fifth day the total weight of the chickens receiving sunlight only through the greenhouse roof is about one half of the total weight of all the chickens exposed to outdoor sunlight or the light from the quartz mercury vapor lamp.

An X-ray photograph, Fig. 4, of the smaller chicken in Fig. 2 shows a lack of development of the leg bones. The bones are poorly calcified and crooked. Compare with this the strong and straight, well-calcified bones, Fig. 5, in the X-ray photograph of the larger chicken in Fig. 2. The condition shown in Fig. 4 is typical of all the chickens of groups four and five. The condition shown in Fig. 5 is typical of all the chickens in groups two and three. The bones of the chickens in group one, *i.e.*, those permitted to run out of

doors, were not so thoroughly calcified nor quite so far advanced in development as those of groups two and three which were exposed to the rays of the quartz mercury vapor lamp.

The retardation in the development of the bones in the chickens of groups four and five was paralleled in the development of the secondary sex characters. The secondary sex characters (comb, etc.) had not begun to develop in the chickens of these groups at a time when they showed an advanced stage of development of the chickens of groups one, two and three.

The chickens receiving cod-liver oil showed well-developed but small bones. These chickens apparently did not like the taste of cod-liver oil, for their appetite seemed poor, and they showed such a slow growth throughout the first part of the experiment that they were all of a smaller size than the chickens of groups one, two and three.

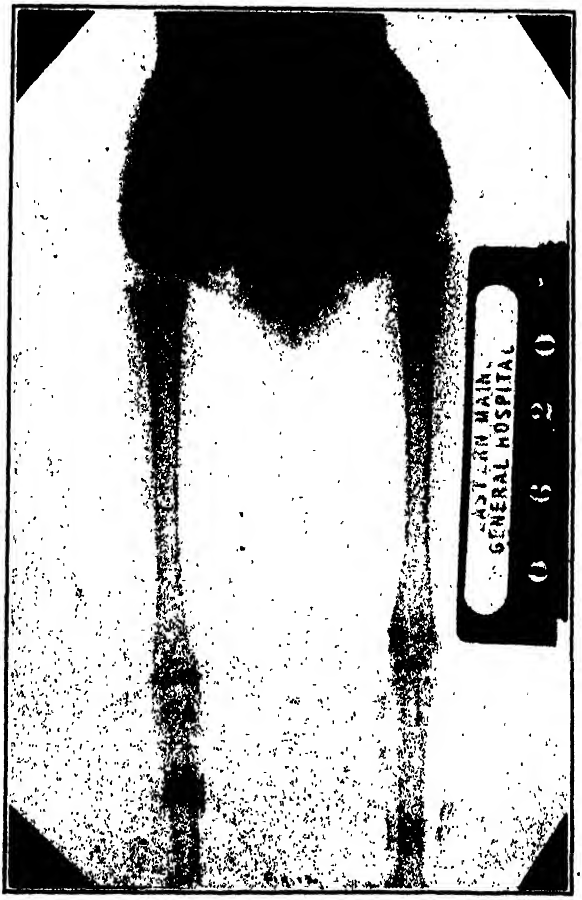

FIG. 5. X-ray photograph of the larger chicken in Figure 2.

While there were fifteen deaths from disease among the chickens in groups four and five, there was only one death among the chickens in groups one, two and three, and it is interesting to note that rats which got into the greenhouse from time to time took chickens only from groups four and five.

Apparently the chickens of groups four and five which were exposed only to sunlight which had passed through the glass roof of the greenhouse have lacked something in the environmental conditions experienced by those receiving either direct sunlight or the light from the quartz mercury vapor lamp. This lack in the environmental condition must be found in the differences in the illumination to which the chickens were exposed, for no differences in diet, excepting in group six, where cod-liver oil was added to the

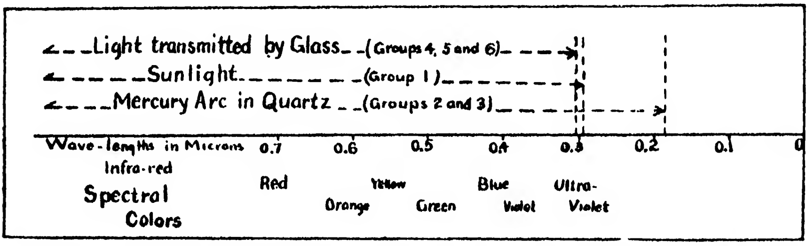

FIG. 6. Spectral colors arranged according to wave length, showing spectral limits of the light received by groups of chickens.

regular diet, produced discernible results. The differences in illumination will be made clear from Fig. 6.

This figure shows an array of the spectral colors arranged according to their wave length, together with the spectral limits of the light received by each group of chickens.

Sunlight contains, besides heat and visible light, ultra-violet light down to wave lengths of about 0.29 microns. Glass transmits some of the heat, all the visible light and the ultra-violet light of sunlight down to wave lengths of approximately 0.31 microns, but does not transmit the small band of ultra-violet of sunlight lying between wave length 0.31 and 0.29. The quartz mercury vapor lamp gives out visible light and ultra-violet light down to wave lengths a little less than 0.2 microns.

It will be seen, therefore, that the chickens, in groups four, five and six, did not receive the ultra-violet of sunlight, having a wave length shorter than 0.31 microns, since this ultra-violet could not pass through glass. The chickens from group one which ran out of doors received in addition to the ultra-violet transmitted by glass the ultra-violet of sunlight contained in this narrow spectral band lying between wave length 0.31 and 0.29 microns.

The chickens in groups two and three received visible light and all the ultra-violet emitted by the quartz mercury vapor lamp, *i.e.*, they were exposed to ultra-violet rays having wave lengths down to approximately 0.2 microns.

Since chickens grow and develop normally in full sunlight and since these experiments show that they do not grow and develop normally in light transmitted by glass it is obvious that the differences in the various groups must be ascribed mainly to this narrow spectral band. This band is so narrow that, by analogy with the visible spectrum, it may be considered a pure spectral color lying in the ultra-violet at the extreme limit of sunlight.

It is not difficult to understand why the antirachitic properties of sunlight are limited to this narrow region of the spectrum. One of the oldest laws of photochemistry (known after the name of the man who first announced it) is Grotthus' law. This law states that only the light which is absorbed can bring about photochemical change. Lambert's absorption law states that the fraction of light which is absorbed is independent of the intensity of the beam which enters the absorbing medium. Lambert's absorption law may be stated mathematically as follows:

$$i = I_0 \varepsilon^{-\mu d}$$

in which i is the intensity of the light after a beam having an intensity I_0 has passed through a layer of the absorbing medium having a thickness d. ε is the base of the natural system of logarithms

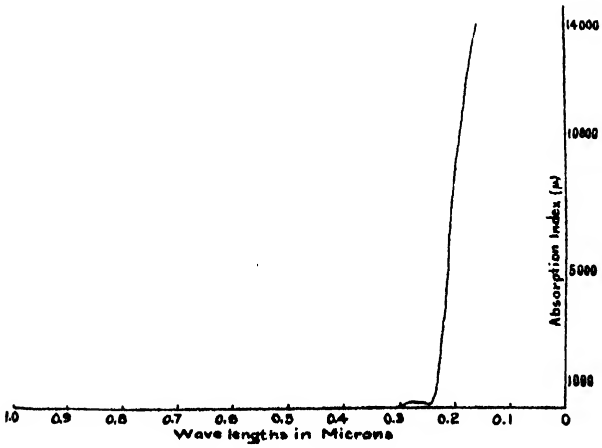

FIG. 7. Absorption spectrum of egg white (probably very similar to protoplasm).

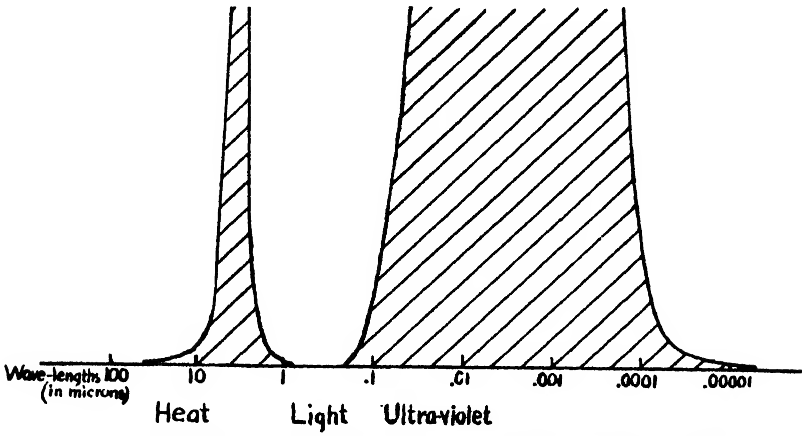

FIG. 8. Regions in the spectrum where protoplasm strongly absorbs.

and μ is the so-called absorption index of the medium under consideration. The value of μ is a function of the wave length of the light, and the absorption becomes greater as the numerical value of μ increases.

The absorption spectrum of a substance depends upon the relation between the value of the absorption index of the substance and the wave length of the light absorbed. The absorption spectrum for egg white its represented graphically in Fig. 7, in which the wave lengths of light are indicated horizontally and the absorption index vertically.

The absorption spectrum of protoplasm probably is not very much different from the absorption spectrum of egg white. It will be noticed that the absorption index of egg white begins to rise rapidly very nearly at the place where sunlight ends.

There are two regions in the solar spectrum where protoplasm especially absorbs; one is in the heat region, and the other in the ultra-violet. This is shown in Fig. 8. (In order to give the figure more convenient dimensions a logarithmic scale is used for the wave lengths. The values of the absorption index are not plotted to scale because we have no experimental data.)

The part of the spectrum having wave lengths greater than 0.8 microns is called the infra-red or heat region of the spectrum. That protoplasm absorbs energy in this region is shown by the fact that we are warmed by the sun's rays. Visible light is only slightly absorbed by unpigmented protoplasm.

We can well understand that sunlight which had passed through a water screen which does not transmit the heat rays of the sun would not warm us. In precisely the same manner glass screens out ultra-violet rays of the kind which are strongly absorbed by protoplasm.

Energy from both parts of the spectrum where protoplasm absorbs strongly is necessary for the normal growth and development of the chickens; and it has been found by experiment that these rays are necessary for the normal growth and development of many other organisms, including man.

That light influences the shape and growth of plants has long been known to the botanist, and is a matter of common knowledge. Any one who has raised plants in a window box knows that the plants must be turned so as to expose all sides successively to the light, if a symmetrically formed plant is to result. This is because the growing tips bend toward the light and the leaves take up positions that expose the greatest amount of leaf surface to the light. Plant physiologists call this bending toward the source of illumination positive phototropism.

The sensitiveness of plants to light is far greater than is commonly supposed. Blaauw found that an oat seedling would bend toward a light of only 0.00017 candle meter but at this light intensity it required an exposure of 43 hours. An exposure of but 0.001 second was required to produce the response at an intensity of 26,520 candle meters. Blaauw conducted experiments using other light intensities and found that not only did the amount of exposure needed decrease as the intensity increased, but that these were related in accordance with a well known law, the so-called "$I \times T$" law of Bunsen and Roscoe. This law was formulated to express the action of light on a photographic plate and states that for a constant amount of blackening (after a standard development) the product of the intensity and the length of exposure is a constant. Blaauw found that this law is true for the oat seedling over the enormous range of intensities indicated above. As the action upon the photographic plate is unquestionably a photochemical effect, Blaauw's results may be taken as very strong evidence that the light produces a photochemical product in the seedling and, further, that the phototropic response only occurs when the amount of this product reaches a certain minimal value.

If one shades various parts of a young oat seedling by small cylinders of tinfoil (which should be supported in such a manner as not to touch the plant) one can demonstrate that it is only the very tip of the young seedling which is sensitive. The bending always occurs a short distance below the tip. We must conclude, therefore, that the effect of the light stimulus is transferred in some manner from the light sensitive tip to the part which bends for the region in which the bending occurs is insensitive to the light.

Since the plant does not possess nerves for the conduction of stimuli many investigations have been conducted in an attempt to

discover the mechanism by which the effect of the light is transferred from the tip to the region which bends. It has been quite conclusively demonstrated that a photochemical product which is water-soluble is responsible for the bending.

It has been shown that the propagation of the stimulus can continue even across a cut surface which separates the region of stimulation from the region of bending. This may be demonstrated if one removes the tip of an oat seedling by a transverse cut and sticks it on exactly in the original position with ten per cent. gelatin. If the tip which has been thus amputated and reset is illuminated from one side, while the remainder of the seedling is kept dark, the non-illuminated part of the seedling will bend after some time toward the source of light. Therefore, a continuity of uninjured cells is not necessary for the conduction of the phototropic stimulus; such conduction can take place even through gelatin across a section of destroyed cells. This fact makes it appear probable that the conduction of the stimulus is effected by diffusion of substances soluble in water even in the uninjured plant.

The extreme sensitiveness of plants to light justifies the belief that only a very small amount of photochemical product is required to initiate the physiological processes which result in the phototropic response.

We do not know whether it is the photochemical product itself which diffuses from the stimulated to the bending region or whether the photoproduct initiates a chain of chemical changes so that there is a sort of physiological amplification of the stimulus. At any rate, a sequence of physiological events occurs through which a modification of plant structure is brought about.

It will clear our notions if we consider for a moment the probable changes which result in the bending plant.

This is not the proper place to introduce a detailed discussion of the mechanism of growth. Suffice it to say that two things are involved. One is an increase in the total amount of substance and the other is a modification of substance into structural elements. This modification into structural elements is called differentiation. It is obvious from a consideration of Lambert's law that the photoproduct will be formed in greater amount on the side that is exposed to the light; hence as transportation of materials in plants occurs most readily in the direction of axial growth the tissues on the side that is exposed to light become differentiated and cease to grow, while those on the other side are still increasing in size.

Light has a profound influence upon the rate of growth of plants. Generally, an increase in illumination retards the rate of growth. Most plants put on the most rapid growth at night, par-

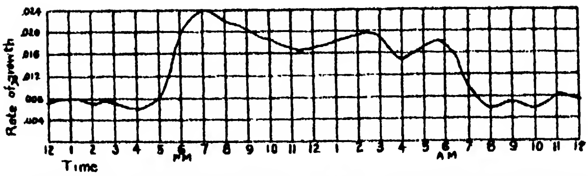

FIG. 9. Variation in rate of growth of four o'clock seedling for one day.

ticularly at eight o'clock in the evening and at two o'clock in the morning.

A number of years ago the author devised a piece of apparatus for measuring and recording the rate of growth of plants. The sensitiveness of the apparatus was such that it would record an increase in length of 1/1000 of an inch. With a rapidly growing seedling the plant will record this increment of growth every fifteen seconds.

Fig. 9 is a record of the growth of the hypocotyl of a four o'clock seedling. Time is measured horizontally and the rate of growth is measured vertically. This curve was made in Cambridge, Massachusetts, during the month of January. It will be observed that the rate of growth began to increase very rapidly at five o'clock when the laboratory began to be dark. There is another rise in the growth curve at about two o'clock in the morning. The two o'clock rise is not as great as that at seven o'clock. This may have been due to the fact that the laboratory was cooler at that time. The curve drops rapidly between three and four o'clock in the morning, when it rises again and then falls as daylight comes. Many other experiments with this apparatus have shown the great sensitiveness of plants to light.

The sharp bend in the curve at four o'clock in the morning is to be correlated with the fact that the day fireman came on duty at this hour and started up the fires in the laboratory heating plant. Curves made on successive days all showed a sharp bend at exactly this time, a rather indirect but effective method of checking on the punctuality of the fireman.

Light influences the rate of growth but does not control it, for the plant continues to grow during the day, and a study of a great many growth curves reveals the fact that growth is a rhythmical process.

It is of course a well-known fact that with the exception of some of the fungi and bacteria, plants can not grow and develop properly in total darkness; the stems are more succulent and there is a deficiency in the amount of mechanical tissue, the green color of chlorophyl-bearing plants does not appear. These conditions are

well illustrated by the ordinary potato sprout which has grown in the cellar.

Plants which have grown in the absence of light are said to be etiolated and in place of chlorophyl a yellow pigment called etiolin is formed. A microscopic examination of the tissues of an etiolated plant shows profound modification in the cell structure. These modifications have been very thoroughly studied by a number of botanists. Sachs, after investigations extending over a period of thirty years, came to the conclusion that a *specific formative material* is necessary for the construction of the various organs of a plant, and, further, that the specific formative material for flowers is formed in the leaves of the plant by the action of sunlight. Sachs believed that this formative material is not identical with the carbohydrates photosynthesized in the leaves, and further, that ultraviolet rays were necessary for its formation. He believed that these ultra-violet rays exerted an important influence upon the growth and development of plants.

MacDougal, in his memoir on the influence of light upon growth, points out that all attempts to establish a direct connection between the action of light on plant tissues and the behavior of these tissues in consequence have so far failed. He says that the basic fact common to all species (except the degenerate chlorophyl-less forms) is that the organs of any plant grown in darkness do not show the same degree of morphological differentiation that is found in corresponding organs of the same age that had been exposed to illumination. The tissues of stems, leaves and floral organs show only limited departures from the embryonic condition when grown in darkness. Comparatively few plants are able to produce a normal abundance of fruit when shielded from the sunlight by glass. MacDougal says further that the physiological effects of exposure to light may become manifest at a time long after the exposure, the effect being carried over even into a succeeding season.

A comparison of the behavior of the normal and etiolated plant offers a demonstration of the fact that growth and differentiation are not only independent but easily separable processes.

While a deficiency in the amount of light results in a delayed or complete failure of tissue differentiation, an exposure to an excess amount of light may result in a premature differentiation as shown by the experiments of Gager.

Gager exposed kernels of corn to the rays from radium. The seeds germinated and grew when the corn was planted, but when the plants had attained a height of a few inches above the surface of the ground growth ceased; an examination of the tissues showed that there had been an excessive amount of differentiation. The

embryonic tissue had been prematurely differentiated into somatic tissues and the plants had died of senility before sexual maturity had been attained. Examples of premature senility of tissues exposed to X-rays are familiar to every physician practicing radiotherapy.

If we interfere with the rate of tissue differentiation in a growing organism the whole process of development may be thrown out of order and the organism may develop into a monster. Hertwig exposed frog's eggs to radium rays and found that the embryos developed abnormally, forming "radium monsters," due apparently to disturbances in the normal sequence of differentiation. Both Gager and Hertwig found irregularities in the nuclear changes which accompany cell division.

Similarly, the failure to develop mechanical tissues in plants grown in the absence of light presents correlated secondary effects upon growth and development of other tissues and organs in the plant, so that a great variety of departures from the normal growth and development are apt to occur.

The stimulating action of light in producing morphological differentiations is not due to any direct action which the rays exert upon a particular tissue, or upon any part of the organ concerned. The stimulative effect of the illumination may be received by one portion of the body and transmitted to another, or impulses may be even communicated to organs not actually formed at the time the stimulating rays were received.

We do not wish to be understood as saying that the exposure to light is the cause of tissue differentiation. As in many other physiological processes it is determined by a great number of conditions. The exposure to light is one of these determining conditions and when the light intensity is reduced below the optimum it may become the limiting factor.

When excessive mechanical strains and stresses are put upon the various parts of a plant by the forces of gravitation, winds, etc., the plant is obliged to meet them by the construction of mechanical tissues. These tissues—the veins in the leaves and the fibro-vascular bundles in the stems—are not only arranged so as to best resist the strains and stresses, but their minute, microscopical structure is such as to give them remarkable mechanical resistance. When a plant is grown in the absence of light these mechanical tissues fail to develop; and while it is true that the differentiation and development of the entire organism is abnormal, a failure in the development of the mechanical tissues is more conspicuous and hence attracts attention. Bleached celery, for example, is, first of all, characterized by being tender. It is lack-

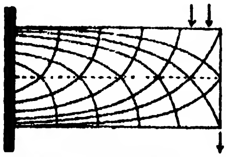

FIG. 10. Distribution of stresses and strains in a beam fastened at one end. (From Thompson's "Growth and Form.")

ing in mechanical tissue, but it is also sweeter than unbleached celery, does not contain as much aromatic oil (celery flavor) and contains an abnormal amount of water. It is more succulent.

The mechanical tissues in animals are also formed in a way to best bear the strains and stresses put upon them. A beam fastened at one end, as shown in Fig. 10, and supporting the load at the outer end, as indicated by the two short arrows at the top of the beam, tends to bend. It is compressed on the lower side and stretched on the upper side. Engineers have determined the direction of these lines of tension and compression. They are illustrated in the figure by the curved lines which cross each other at right angles.

Any engineering structure always contains compression and tension members which in good engineering practice are laid down along the lines of stress and strain.

Fig. 11 shows the stress and strain lines in a crane head and in the head of the femur bone.

Fig. 12 is a photograph of a section of the head of a femur.

The femur consists of a hollow shaft of bone expanded at the ends into articulating heads. It is filled with marrow and contains at the ends a meshwork of bony plates called trăbeculae. It will be seen from the figure that these trabeculae are laid down along the stress and strain lines. According to the investigations of Koch, not only are these trabeculae laid down precisely along the stress

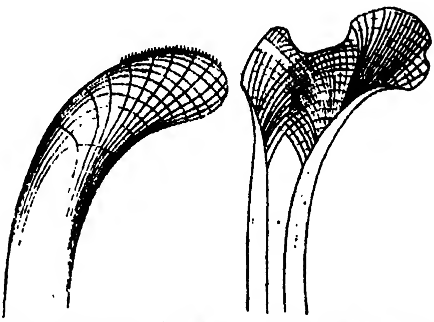

FIG. 11. The stress and strain lines in a crane head and in the head of the femur bone. (From Thompson's "Growth and Form.")

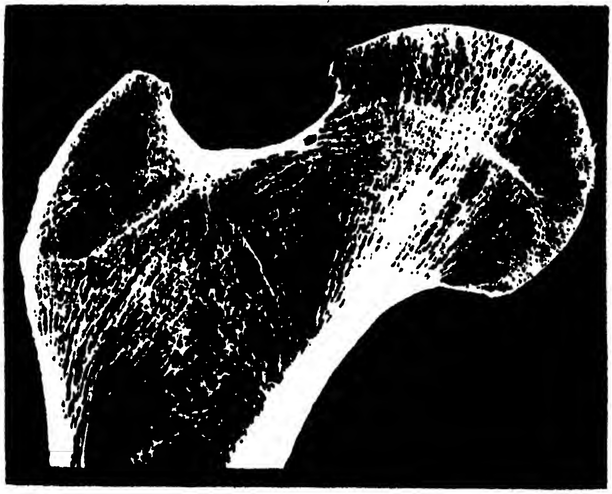

FIG. 12. Photograph of the arrangement of trebiculae in head of femur. (From Thompson's "Growth and Form.")

and strain lines, but the thickness of the trabeculae are proportional to the loads placed upon them. All the bones of our bodies are characterized by this remarkable architecture, an architecture in exact agreement with the practice that has been developed by our best engineers.

Furthermore, the trabeculae seem to be constantly demolished and formed anew, for if the pattern of the stress and strain lines be altered by a change of posture or by such changes as occur when broken bones are set out of line or from the transplantation of bone in bone grafting, it will be found that in a very short time the trabecular meshwork has taken on a new configuration which conforms with the new stress and strain line pattern.

Similarly, in plants, when stress or strain is placed upon a member, as when, for example, fruit is forming, the strength of the supporting members, without any apparent change in configuration of the mechanical supporting parts, have their tensile strength increased so as to support the additional load.

Pfeffer experimented with sunflowers and was able to increase the tensile strength of the sunflower stem from 160 to 300 grams in three days by merely loading the plant with weights, and a few days later the tensile strength had increased to 400 grams, an increase of over 250 per cent.

It is as if an engineer could construct a bridge that would automatically arrange its parts, adding new members or removing them as the case might be, so that the bridge would always have the best sort of configuration to support the new or shifted loads.

The deposition of the bony material in a developing child is one of the processes of tissue differentiation referred to above. In the absence of ultra-violet light this differentiation does not take place properly.

Fig. 13 shows sections of the bones of an animal suffering from rickets. There is a failure to deposit calcium and phosphorus salts in such a manner as to meet the mechanical demands. When a child learns to walk and puts its weight upon the bone the trabecular meshwork that would normally be formed to meet the stresses and strains is not built and they can only be met imperfectly by the curving of the bone, and greenstick fractures easily follow.

Bowlegs may be due to mechanical deficiencies of the bones rather than to putting the weight of the body on them at too early a period. We do not know all the forces which are brought into play in building the mechanical structure of bone, but it appears as in the case of the plant cited above that the weight placed upon it acts as a necessary stimulus to which the organism responds by laying down and strengthening mechanical structures precisely adapted to bear the weight.

It is known that ultra-violet light does not penetrate the organism far enough to reach the bones. This light is absorbed by the surface layers of the tissues upon which it falls and its stimulating action must, therefore, be transferred in some manner to the developing bone.

The same condition is true in plants, for it has been found that illuminating one part of the plant affects the differentiation and development of parts not exposed to the light. Now, in plants there

Fig. 13. Photographs of sections of bones from an animal suffering from rickets. (From MacCallum's Pathology.)

is no specialized nervous tissue which serves to transmit stimuli, and it seems reasonable to believe that some photochemical product is formed in both plants and animals. It is this photo-product or "formative material," as Sachs called it, which is necessary to bring about the differentiation.

In plants this material is formed in the tissues exposed to the sunlight, but it appears that in animals the substance stimulating differentiation may either be formed directly in the organism by exposure to ultra-violet light or it may be taken in with the food, for we know that addition of cod-liver oil to the diet has a beneficial action in regulating faulty calcium metabolism. The recent investigations of Hess and Steenbock and others have shown that when certain substances as cotton seed oil, linseed oil, lettuce or dried milk are exposed to the ultra-violet light and then added to the diet, the diet is rendered anti-rachitic; or speaking, more generally, the diet becomes suitable for stimulating normal differentiation.

It may be instructive to draw an analogy between the morphogenic action of light and the action of light upon the photographic plate. When we expose the photographic plate in a camera a latent image is formed in the sensitive film of the plate. This image is invisible to our eyes. The plate appears exactly the same before and after exposure. The latent image is not to be confused with the image which will appear upon the plate when it is developed. By latent image we mean the peculiar photochemical change which has taken place in the silver grains of the plate and which has transformed them into a developable condition. When the plate is subsequently developed, it is found that only those silver grains which have been brought into the developable condition are affected, providing the developer is not too warm.

The sensitiveness of the plate does not depend upon the dispersion of the silver salt in dry gelatin, for the fresh fluid emulsion, before it has flowed upon the plate, needs to be carefully protected from the light.

In the development of a photographic plate the silver grains are reduced while the developer is oxidized. It is conceivable that as chemists we might have been interested rather in the oxidation of the developer than in the reduction of the silver salts; in which case every photographer would have learned that if he wished to oxidize an alkaline solution of hydroquinone or pyrogallic acid (or any other developer) at room temperature, he could add to the developer silver salts dispersed in gelatin, and it would be an essential detail that the gelatin and the silver salts must have been previously exposed to the light. A brief exposure would be sufficient

and the exposure could have been made several months in advance.

Moreover, our photographer would also learn that the emulsions of the silver salts in gelatin varied in their sensitiveness to light. There would be fast or slow emulsions depending upon the method used in "ripening" them, and his familiarity with the process would undoubtedly in time blind him to the mystery of the mechanism and he might cease to wonder why it was necessary that the emulsions be exposed to light in order to oxidize the developer, just as he has now ceased to wonder about the mechanism through which the light makes the photographic plate developable.

Let us now compare the blood to the photographic emulsion. The blood flowing through the baby's arm may be exposed to ultraviolet light of a suitable wave length. Then, after this exposure, when it comes into contact with the embryonic bone tissue, the latent image produced by the light in the blood may be developed by the chemical interactions which occur in connection with the metabolic changes having to do with the differentiation of bone tissues. In a like manner we may consider that the radiated foods of Hess and Steenbock carry a latent image capable of influencing metabolic changes having to do with differentiation of bone tissues.

We do not possess at the present time sufficient information to describe further the nature of these photochemical products or the chemical changes which they induce. We only know that they are necessary for a proper growth and development of the organism.

We may carry our analysis somewhat further, however, by discussing briefly the nature of photochemical change. If every molecule and atom in a chemically reacting mixture were in a suitable condition to take part in a chemical change, every chemical reaction would proceed with the velocity of an explosion. That all chemical reactions are not explosions testifies to the fact that only a certain fraction of the atoms or molecules are in such a condition at any one time that they can take part in the reaction.

When we warm a mixture of chemicals in a beaker in order to increase the rate of reaction more of the chemically passive atoms or molecules are changed into a chemically active condition and the speed of the reaction is a measure of that fraction of the atoms or molecules that have been brought into the activated condition.

If we accept for the time being the electron theory of sub-atomic structure, the atom may be compared to a minute solar system, the electrons taking the place of the planets and revolving about a central nucleus (or sun); and according to the theories of Bohr, Summerfeld and others, when the atom is chemically activated some of the electrons which are revolving in the outer orbits are caused to revolve in orbits which are farther flung from their central nuclei,

so that they revolve in highly eccentric orbits after the manner of comets rather than the more nearly circular orbits as do the planets.

These outer electrons seem to serve in some way in linking the atoms together to form molecules and it is believed that one of the first steps in a chemical union is the throwing off of these valency electrons into farther flung orbits and this has been identified with the chemical activation of the atoms.

The energy required to throw these electrons into far flung orbits may be derived from the heat energy of the reacting mixture, and it is supposed that this energy is acquired by the atoms at a moment of molecular collision.

It is known that when light, particularly ultra-violet light, falls upon some substances they are caused to give off electrons (photoelectric effect). These electrons probably are derived from the atoms of the material upon which the light falls. It is, therefore, easy to understand how an energy like light can hurl electrons into far flung orbits and thus chemically activate the atoms. When atoms are activated by absorbing light energy we refer to the chemical change which ensues as photochemical. If the atoms are chemically activated by heat energy described above we call the change thermochemical.

There are many kinds of atoms and molecules which can be activated by light energy and there are certain kinds of chemical reactions, such as the photosynthesis which occurs in green plants, which can be brought about only by light energy. These reactions are referred to as specific photochemical reactions. The experiments upon the chickens referred to above seem to indicate that the formation of the latent image through which tissue differentiation is brought about is a specific photochemical reaction.

It is well known that silver salts have their sensitiveness greatly increased when they are dispersed in the gelatin of the photographic plate. Moreover, this sensitiveness is further enhanced by the process of "ripening" the emulsion; and during the ripening process certain physical changes occur in the relation between the silver grains and the surrounding gelatin. We may suppose that this physical alteration consists in establishing certain molecular orientations of the silver salt molecules and of the gelatin molecules at the interfaces where the silver grains and the gelatin are in contact. It is perhaps this molecular organization to which we must look for an explanation of the fact that once the silver salt molecules have been brought into the chemically active condition by the exposure of the plate to light they are able to remain in this activated condition until the plate is developed.

Similarly may we not suppose that certain substances in the blood stream and in the tissues of the plants, cottonseed oil, etc., may be chemically activated by ultra-violet light so that a photochemical product is formed that can only be developed when these substances have been brought into the places where they will initiate differentiation?

Physiologists have named substances like those contained in cod-liver oil which catalyze certain physiological processes "vitamines." The above considerations may throw a great deal of light upon the nature of vitamines. They seem to be substances with chemically activated atoms which are capable of hastening the speed of physiological changes so that they proceed at body temperatures and at velocities which would otherwise necessitate very much higher temperatures.

Whatever theories are proposed to explain the reactions, the fact remains that most plants and animals, including man, are as dependent upon the ultra-violet energy of sunlight for normal growth and development as they are upon the heat energy of sunlight. Other physiological functions besides bone development are interfered with when the organism is deprived of this kind of radiation. The body is more susceptible to the inroads of disease. A well-sunned body furnishes a high degree of protection against tuberculosis and the progress of the disease, even after it has been contracted, is often quickly and permanently checked. Window glass has unquestionably accelerated the speed of civilization, but man has paid the price.

RADIO TALKS ON SCIENCE[1]

WHY THE EARTH IS A MAGNET

By Professor W. F. G. SWANN

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If we carry a freely suspended magnetized needle over the surface of the earth, we find that at each place it points in a definite direction characteristic of that place; and, if we draw lines in such a way that they are everywhere parallel to the direction in which the needle points, we shall find that these lines emerge from the earth in a more or less concentrated region near the south pole, and, after spreading out, converge in a more or less concentrated region near the north pole. These lines mark out what are called the earth's lines of magnetic force, and their existence shows that the earth is a magnet. The question of why it is a magnet is one of the most puzzling conundrums which science has to solve. We can not lightly dismiss the matter by saying that the earth probably got magnetized somehow or other at some time or other, and that is the end of the matter; for such permanent magnets as we are familiar with lose their magnetism when heated to temperatures much less than those which we believe to prevail in the earth's interior.

We know that a current of electricity gives rise to magnetic effects; and, as a matter of fact, if we were to wind a lot of insulated wire into a ball, with all the turns going round in the same direction, and then pass an electric current through the wire, the ball would exhibit magnetic properties very similar to that of the earth. Even if we should confine the windings to the surface of a sphere, the earth's magnetism would be roughly duplicated. This effect would not be destroyed by temperature increase so long as we maintained the current; and we are thus led to inquire whether it is possible to attribute the earth's magnetism to currents on its surface or in its interior.

An electric current is nothing but electricity in motion. Now the earth's surface is coated with a charge of electricity of sufficient amount to result in a difference of electrical pressure or

[1] Broadcasted from Station WRC, Washington, December 31, 1924, under the auspices of the Smithsonian Institution and the direction of Dr. Austin H. Clark.

potential between the earth's surface and a point one yard above it one and a half times the difference of electrical pressure between the terminals of our lighting circuits. This charge is in motion as a result of the earth's rotation, and it may be expected to produce a magnetic field. When we submit the matter to calculation, however, the magnetic field comes out one hundred million times too small.

In order to appreciate a few of the possibilities available for accounting for such a phenomenon as the earth's magnetism, it is necessary to remind you of a few of the things which the scientific investigations of the last thirty years have taught us regarding the structure of matter. We believe that structure to be entirely electrical, and that, in its ultimate make-up, only two fundamental kinds of brick are to be found. These are the electron and the proton. The former is the ultimate unit of negative electricity. Its size is so small that if we should magnify a drop of water to the size of the earth, the electron would, on the same scale of magnification, attain a size only just visible under our most powerful microscope. Its mass is about the one thousandth of the one millionth of the one millionth of the one millionth of the one millionth of the mass of a collar stud. The proton has a mass about 2,000 times that of the electron, but its diameter is about 2,000 times smaller than the diameter of the electron, so that if the proton should be magnified to the size of a pin's head, that pin's head would, on the same scale of magnification, attain a diameter equal to the diameter of the earth's orbit around the sun.

The atoms of which matter is composed are themselves built up out of protons and electrons, and the general structure comprises two parts, a central nucleus composed of protons and electrons in close proximity, with electrons revolving in orbits about that nucleus, just as planets revolve around the sun. The hydrogen atom, the simplest of the atoms, has as its nucleus one proton, and around this, at a distance of about the one two hundred and fifty millionth part of an inch, there revolves an electron. To magnify the picture to sizes more commensurable with those to which we are accustomed we may say that if we reduce the sun to a diameter of four miles, and leave the earth at its present distance and with its present size, the picture presented would simulate the hydrogen atom, with the sun as the nucleus and the earth as the electron.

The atoms of heavier substances like iron have many protons and electrons in their nuclei, and many electrons revolving around them. In the case of solids, moreover, particularly those solids which are good conductors of electricity, we believe that many of

the electrons are able to come out of the atoms and wander about more or less freely between them.

Now a cubic inch of a solid such as the earth contains a very large number of protons and electrons, a very large amount of positive and negative electricity—so much, in fact, that if we could separate out all the positive electricity and concentrate it at one point, and all the negative electricity and concentrate it at another point one inch away, the two would attract each other with a force of 36 hundred million million million tons. The neutrality of these two enormous amounts of opposite electricity is like the neutrality of two huge armies which are so interlocked that they have no attention for anybody else. If one of them should weaken in strength, numbers or any factor which affects its power, even to a slight extent, the other could afford to let loose forces to very drastic ends. So it is with the very large amounts of opposite electricities in the earth. If one of them could operate alone, the current produced by its rotation would give a magnetic field five million million million times that of the earth. If the two electricities were spread over spheres of slightly different size they would not quite compensate, and a little magnetic effect would be left over. It would only be necessary for the two spheres, each of about the size of the earth, to differ in diameter by about five hundred thousandths of the millionth part of an inch in order to leave a residual sufficient to provide for the earth's magnetism. When we submit the matter to calculation, however, we find that the forces interlocking the two kinds of electricity are such as to prevent even such a slight separation as this unless we invoke for that separation agencies of such enormous power that we know of no cause which could be responsible for them.

The centrifugal action of the earth's rotation on the free electrons within it would tend to make these electrons fly to the outside and would so increase their efficiency in producing the magnetic effects which we observe, but the effect is a hundred thousand million million million times too small.

The weight of the electrons would tend to cause them to congregate towards the center of the earth, an influence which would be resisted by their mutual repulsions as they came closer together. However, here again the lack of complete compensation of the magnetic fields produced by the positive and negative electricity in the earth results in a magnetic field only the one thousandth of the one millionth of the one millionth of the one millionth of the earth's magnetic field.

The great temperature of the earth's interior will cause the volume of the electrons in the hot parts to swell out, just as a gas

swells out when heated; and here again we have an agency tending to destroy the complete balance of the positive and negative electricity with the result that a magnetic field should be produced. When we submit the matter to calculation, however, we find that we can only account in this way for a magnetic field the one hundred thousandth of the millionth of the millionth of the earth's magnetic field.

These instances serve to illustrate the practical hopelessness of any attempt to explain the earth's magnetism as a result of redistribution of the charges within it brought about by such agencies as we have knowledge of. There are, however, ways of obtaining currents of electricity other than by the rotation of charges which have been more or less separated from each other. Thus, if the opposite charges are completely superposed, but the charge of one sign moves with a velocity slightly different from that of the charge of the opposite sign, we shall get a current. As a matter of fact, nearly all the currents used in practice are produced by the relative motion of completely superposed distributions of electricity. If there were any way in which we could see reason why the negative electricity in the earth should move a little faster in its rotation than the positive, faster to the extent of only one part in seventy thousand million million of the total velocity, we could account for a state of magnetization comparable with that which we find in the case of the earth. Here again, however, nature provides us with no obvious mechanism to account for the desired state of affairs.

I have referred to the fact that an atom of matter is to be thought of as a central nucleus with electrons revolving around it, just as planets revolve around the sun. Now these revolving electrons are the equivalent of a current of electricity; and, in cases where the effects do not mutually cancel in the same atom, they endow the atom with the properties of a magnet. We believe, for example, that the atom of iron is a little magnet, and that it derives its properties in some such way as this. However, the rotation of the electrons in the atom endows it with another property, the power to act like a gyroscope or fly-wheel. If you mount a fly-wheel on a frame and try to make the frame rotate about an axis which is not parallel to the axis of rotation of the fly-wheel, you will find that the fly-wheel brings into play forces which cause it to exhibit a strong desire to turn its axis parallel to the axis about which the frame is rotating. The experiment may be tried with an old bicycle wheel set into rapid rotation. If you incline the axis of the wheel to the vertical, and then run around in a circle, you will feel the forces tending to make the wheel stand

with its axis upright, and the behavior of a bicycle wheel of this kind affords an interesting experience to any one who has never before become familiar with the action of a gyroscope.

Now, as I have said, the atoms act like gyroscopes on account of the revolutions of the electrons within them, and atoms of this kind in our earth will tend to turn so that their axes are parallel to the earth's axis of rotation. If they could all turn this way, the cooperation of their magnetic effects, now all in the same direction, would give rise to a very large magnetic influence of the earth. However, we know that, at all times, the atoms experience an irregular motion as a result of jostling against one another. It is in fact this motion which we recognize in the phenomena associated with heat. The jostling motion tends to annul the gyroscopic motion of which I have spoken, and it succeeds to the extent of reducing the resulting magnetic effect to an amount about ten thousand million times too small to account for the earth's magnetism, even in the most favorable case.

You will doubtless think that, since this talk is entitled "Why the earth is a magnet," I should have spent less time in explaining why it should not be one. As a matter of fact we can not say that we know with any certainty why the earth is a magnet. Before branching out into speculation, however, it is desirable to examine carefully all the possibilities which a rational survey of the situation would suggest. Such a survey seems to lend considerable evidence for the belief that we may have to seek the solution of the earth's magnetism in a slight departure from those fundamental laws of electricity with which we have been familiar in the past. The fact that either the positive or negative electricity contained in the earth would, if rotating alone, with the earth's angular velocity give rise to a magnetic field five million million million times that of the earth suggests that a very slight modification of the laws for positive and negative electricity may provide a key to the situation, for then the complete compensation between the two would be destroyed. Now it is possible to make such a modification in a consistent manner. The details are far too complicated for an exposition in which one can reach his audience only through the voice, and all that I can say is this: One of the characteristic features of the classical viewpoint is that, in the case of a continuous current flowing in a circle, the magnetic effects depend only upon the amount of the electricity and upon its velocity. However, the electricity has other characteristics of motion besides velocity. It has acceleration, for its velocity is changing, and it has rate of change of acceleration, for the direction of the acceleration is changing, and so on. The modification of which I speak

invokes these to a very small extent in the case of the positive electricity, while the ordinary views prevail in the case of the negative electricity. The result is a lack of complete annulment when the positive and negative rotate together. I may add that certain other features evolve at the same time. For the modification of the laws results in the conclusion that, as a result of the rotation, the positive electricity should suffer a slow death, so that there would be a continual accumulation of unbalanced negative electricity. Now this is just what is wanted to account for one of the most puzzling problems of atmospheric electricity, the fact that a current of negative electricity is continually streaming away from earth into space, and yet the earth, like the widow's cruse of oil, does not suffer apparent diminution in its net amount. The rate of death of the positive electricity is very small, so small in fact that it would take a hundred million million million years for one half of one per cent. of the positive electricity in the earth to disappear. I fear, therefore, that it will not be in your time or in mine that we shall find direct evidence of that death of the substance of our earth.

TREE RINGS AND CLIMATE

By Professor A. E. DOUGLASS

UNIVERSITY OF ARIZONA

If trees could talk, they would complain bitterly of snowy weather like this, for the cold stops their growth and offers serious chances of injury. But ages of experience have shwon them how to protect themselves by many adaptations, of which one is a change in the character of the growing wood. This altered effect in the trunk appears in the form of annual rings, which thus are really "scars" of the yearly ordeal of cold through which northerly vegetation goes.

Now a scar tells something of its own story, and we might expect the rings to tell us something of the various experiences of the tree. And so they do, and each ring becomes an annual report, not necessarily of the winter, when growth is stopped, but rather of the spring and summer when growth is most rapid. If one growing season differs from another, the difference is highly likely to show in the rings. And in the successive rings of a tree we get its life story. In the east that story depends on many conditions, such as too much other vegetation, competing for every inch of ground, too much water in the soil, and especially such terrible pests

as the gipsy moth in eastern Massachusetts (I have seen the effect on the shores of Buzzard's Bay) and the chestnut blight; and a tree story here might tell chiefly of such experiences and very little directly of the weather. But conditions in the great pine forest of Northern Arizona are so different that the easterner can scarcely realize them. There the trees are far apart with little or no undergrowth between them: they are miles from any water courses and the ground is dry much of the year. The story in the trees is largely climatic and deals with rainfall and snowfall or, as the botanists say, "moisture is the controlling factor."

This Arizona tree is the yellow pine, much used for lumber. The altitude above the sea, of 5,000 to 9,000 feet, is high enough to make the summer climate lovely and the winter climate cold and bracing, with quantities of snow. So the rings are well marked and very reliable and this tree has proved wonderfully adaptable to this study. Many interesting facts have come out. In the first place, similar sequences of rings are found over very large areas. What that means is this. A heavy winter snowfall in Flagstaff which supplies abundant moisture for the trees there extends over hundreds of miles and supplies abundant moisture in northwestern New Mexico, 225 miles away, or over in the Charleston Mountains near Las Vegas, Nevada, an equal distance west. A dry year in Flagstaff is dry in the other places also. Even at much greater distances the resemblances are enough to enable us to carry dates across. For instance, the yellow pine ring for 1851 is small all the way from Santa Fe, New Mexico, to Fresno, California, a distance of eight hundred miles with nearly four hundred miles difference in latitude. Now this is evidence of a climatic similarity across those great distances and can be used in the study of climatic districts, but I have used it under the auspices of the National Geographic Society in actually determining the date of cutting of certain Spanish beams used in kivas of the Pueblo Indians. It was wonderfully fascinating to make a cutting from an ancient beam in the abandoned part of the village of Oraibi in northern Arizona and find rings that perfectly matched the Flagstaff tree growth and then be able to say that the tree was cut in a certain year a little less than three centuries ago. Fortunately, this society is interested in further research along this line in connection with their excavations at Chaco Canyon under the direction of Mr. Judd.

Another very interesting bit of information has come from these Arizona trees. Since they tell wet and dry years, they can be and are used for the study of drouth. At first I merely compared the trees' growth in given years with statements of famine and flood in the history of Arizona and New Mexico. Then when these seemed to agree I made a more formal search for drouths. This was really

done because various persons interested in reclamation wanted to know how big the reservoirs would have to be in order to take care of dry years. I found easily enough the historic drouths of 1682–6, 1748, 1777–82, 1822, 1879–87 and 1902–4. But I found also a very severe drouth from 1729 to 1741 and a still worse one from 1573 to 1587. Both of these were felt from New Mexico to California. So the trees give us much historical information of value in engineering.

And this brings us to the age of these Arizona trees. My collection includes ten trees whose age is five hundred years and one whose life covers six hundred and forty years. These figures are probably very accurate, for they are reached not merely by a process of ring counting but by a minute comparison between hundreds of trees so that every possible error is avoided. In fact, no tree record is used unless it has been compared with others and found to show minute similarities that can be recognized. The early counting of rings in these yellow pines was later found to have four per cent. of error, due mostly to missing rings which in the outer parts of very old trees may be readily overlooked. These were all discovered by comparing many trees together.

Of course, I have collected sections or cuttings or samples of rings of other trees than the Arizona pines. Of these others the most interesting are the big trees or *Sequoia gigantea* of California which grow at elevations of five to seven thousand feet in the high mountains east of the great central California Valley. My chief collection comes from the King's River country east of Fresno near the General Grant National Park, where much lumbering has been done. I do not like to think of those giant trees being cut down and I hope that no more will be sacrificed, but yet it is the stumps which have supplied most of my material. I have in all thirty-three cuttings from there, two from the grove east of Porterville and this summer five small cuttings from fallen trees in the Calaveras Grove which I obtained by kindness of Mr. Whitesides, who owns the grove. Of course many interesting facts have come out from this study of the sequoias. The rings do not tell quite so accurate a climatic story as the yellow pines and yet on the high and dry ridges it is still a story of moisture. The basins between the ridges have streams flowing through in the summer and the rings are larger and more uniform. There is a great dependence of the growth on the proximity of running water. And thereon lies the blame for overestimating age in many cases. The oldest tree so far found, whose age is absolutely reliable, shows a ring which grew in 1306 B. C. That makes an age which to-day would be over 3,230 years. That particular stump was found by Ellsworth Huntington more than ten years ago.

Now that age was determined by an inter-comparison of some twenty-three trees, mostly over 2,000 years old. That comparison took me a year and after it was done there was a possible error of one year, namely, a possible extra ring which occasionally seemed to show for the year 1580 A. D. So an extra trip was made to the King's River region to settle this question and twelve new specimens were secured which verified this supposed ring as real. So it is probable that the date of the beginning of this tree is correct. I have looked at thousands of stumps and failed to find anything older. In the trip referred to, I looked at some living trees, measuring their size and testing the size of the rings near the outside in sundry burnt places and judging the effect of relation to water, but did not get anything of longer life than this. The General Grant tree may be 2,500 years old. I have not yet seen the General Sherman in the Sequoia National Park. A stump of 25 to 30 feet near the General Grant Park had grown near a stream and had only 1,500 rings. A similar stump in a drier place in the Porterville region has 3,100. It is the stump from which a specimen was taken for the Centennial in 1876. The oldest tree, as mentioned, grew near the Converse Hoist close to the General Grant Park and was only about 22 feet in diameter. The famous Dance Hall stump in Calaveras Grove, mentioned by Mark Twain, was a quick-growing tree and probably did not have more than 1,500 or 1,800 rings. On the whole, the Calaveras trees are not so old as those farther south. The point that proved important at Calaveras was that the rings could be identified with those in the other big tree groves. So that now we know that all the big trees give a somewhat similar story.

Now what is all this for? It is to get all the information we can about climatic conditions in past time and in distant places. Our yellow pines give us the drouth and rain history of five or six hundred years in Arizona: the sequoias give us data for more than three thousand years. We can therefore make extensive historical studies and especially we have a chance to test climatic cycles or recurring climatic conditions by the aid of data which go back far beyond the use of instruments for measuring rainfall or temperature, even though these tree records are not quite so accurate. Yet they are accurate enough to have a very real value. This I became sure of two or three years ago. I had studied the eleven year solar or sunspot cycle in the Arizona trees and found it there for most of the time, but from about 1650 to 1730 or 1740 it disappeared, so that I was in some doubt whether the trees could be reliable. However, I published the facts as I had found them and said that about 1700 the solar cycle flattened out. Three years later,

a letter from the noted English astronomer, E. W. Maunder, of the Greenwich Observatory, said that he had been studying old sunspot observations and that betwen 1645 and 1715 there were none or very few seen and that the trees ought to show this if they were giving real solar history. The dates agreed so well with my time when the trees failed to show the solar cycle that confidence in the tree ring history seemed well placed, and it appeared pretty certain that the solar cycle has been operating since 1400. The sequoias are extending that history farther back. We have constructed an instrument for studying cycles, for the mathematical processes are very long, and we have some 500 curves prepared for analysis. We are beginning to see certain cycles which rather dominate things, and it seems as if they were related to solar changes, but it is perhaps a little early to speak of them with precision.

Finally the study of tree rings will give us further knowledge of the distribution of conditions about this world of ours. Of course trees do not have the same climate everywhere and so show different responses, but making allowance for that we get some knowledge. Thus the pine trees about the Baltic Sea give a very accurate history of the sunspot cycle for the last century. When this study is extended to all parts of the world we shall have certain general information which would be too expensive to get in any other way. In carrying out that idea the Carnegie Institution has assisted in collections from a large number of locations in the southwest.

So Good Night. I thank you.

GROWTH IN TREES

By Dr. D. T. MacDOUGAL

CARNEGIE INSTITUTION OF WASHINGTON

Almost every one has seen young leaves on a tree unfold and lengthen in the spring. Branches shoot out in the same way and seeds sprout or "come up" out of the ground. The mechanical forces involved in the growth of plants, like scores of the commonest happenings all about us in nature, are not widely or well understood.

Many will be surprised to hear that growth is due to the action of mechanical forces at all, but this is clear when one sees rocks split apart by roots which enter small crevices when they are tiny rootlets and then, as they grow larger, separate or lift masses of stone weighing hundreds of pounds. Mushrooms with tender,

fragile stalks come up beneath pavements and lift the bricks out of the pattern.

The roots of one kind of plant are driven through the ground by a pressure which may be as great as five or six hundred pounds to the square inch. Large roots and underground stems of one plant actually may be pierced by the small roots of another plant which chance to grow in the direction where the large root is in the way.

Most striking of all is the growth of a tree. Giant columns of trunks and great branches are thrown up two or three hundred feet in the air. It is true that this great weight is not all lifted at once, but it must all be lifted some time and somehow. The machinery by which this is done is simple enough in plan but quite complicated in operation. The power for operating the machine is derived from sunlight. A steam engine converts water into steam by using the heat from fuel. Similarly, the leaf of a plant converts water and carbon dioxide gas which it gets from the air into sugar. This sugar is actually burned in the plant to obtain power, or sometimes it may be converted directly into wood.

Underneath the bark of all trees is a very thin, silvery layer of living, growing cells, the cambium. These cells use up the sugar made by the leaves to build new layers of wood on the outside of those already formed. These new layers are sometimes not so thick as a dime. In other cases they may be a half inch thick. This new wood is added to the trunk of the tree every year. At the same time other living cells in the buds use sugar in building new cells on the ends of branches, by which the branches are made longer. A branch of the famous Monterey pine tree may elongate as much as six or ten feet a year. If a growing morning-glory vine is measured every day, it will be found to add several inches to its length in twenty-four hours.

These facts about the growth of plants are one part of my story. The other important part is that of the movement of the sap in trees. Water from the ground must be carried up to the leaves of all parts of the top of the tree. At the same time the sugar formed in the leaves must be carried down the entire length of the tree trunk, even to the extreme tips of the tiniest rootlets which may be many feet away from the base of the tree. In some cases this sugar which the roots use for food must be carried downward as much as four hundred feet.

The pipes through which the liquids move upward and downward inside the plant are just beneath the living, growing layer of cells. Some of these pipes are like long tubes. Others are like

organ pipes welded together with the ends overlapping, the connection between each two such pipes being through a thin membrane or strainer with minute holes in it like a sieve. The sap is pulled up through this pipe system by the power of the sun, but that is an entirely separate story, which I may tell you some day when I learn about it by experiments on some of the famous Big Trees or redwood trees of California.

Thick liquids like molasses flow most readily when they are warm. It is true, too, that coal burns best in a hot fire. Just so, a tree grows fastest when it is warm, but of course it must not be too warm. When the physician wishes to know whether the body of his patient has become too warm or too cold, he uses a small thermometer which is placed in the mouth with its bulb underneath the patient's tongue. When we wish to obtain similar knowledge about the temperature of a tree, we cut a small hole in the skin or bark of the tree and place the bulb of a small thermometer in contact with the soft growing cells underneath the bark. If the air temperature is then measured by a second thermometer, suspended from a branch nearby and shaded from the sun, some very interesting comparisons can be made.

It will soon be evident to any one who performs this simple experiment that the tree never gets quite as cold as the air. On the other hand, it never becomes quite as hot. This protection of the living cells from extreme heat and cold is one of the uses of the bark to the tree. The second fact that will be seen by one using two thermometers in the manner I have described is that the tree is not coolest at the time when the air is coldest, but an hour or two later. Similarly, while the hottest part of the day, as we feel it and as the thermometer shows it, is usually shortly after noon; the tree does not reach its highest temperature until later, perhaps as late as three or four o'clock in the afternoon.

Nearly all kinds of our common trees cease to grow when the temperature under the bark falls below forty-five degrees, which is still twelve or thirteen degrees above freezing. Not many kinds of trees live in places where their cells become hot enough to stop growth. I have not found any kind of a tree or a shrub which can grow after its cells reach a temperature of one hundred and twenty-five degrees. Only certain special kinds of plants which live in hot deserts are able to remain active when it is as hot as this. Trees like the pines, the beech, the maple and the oak do not grow when their trunks become warmer than our bodies, that is, warmer than about one hundred degrees.

The living cells of the tree are not actually killed by these high temperatures, for I have found that the stems of a cactus plant in

Arizona may become as warm as one hundred and thirty-six degrees and still live. The tree likewise can endure very low temperatures without damage. But, although life persists, growth will not continue when the temperature is either too high or too low. The growing layer on the outside of a tree is most active in creating new living cells, and hence most wood is formed, in the moderate favorable temperatures.

The intense sunlight and heat of a warm day make much sugar in the leaves and this also speeds up growth, but other effects are produced which make exact measurement difficult. I have designed a special instrument called a *dendrograph* for making such measurements. This instrument is fastened to the trunk of the tree to be measured and has a pen which traces each tiniest change in the thickness of the trunk on a sheet of paper.

Having thus furnished the tree with a pen, it faithfully writes its own diary, if only we keep it supplied with ink and paper.

The first thing which arrests our attention in these self-written stories of the trees is the fact that the trunk, especially the trunk of a pine tree, begins to shrink a little in the morning and continues to do so until afternoon. This apparent shrinkage, even during the time of the day when new living cells are being formed in the growing layer inside the trunk, is due to the fact that water is being sucked out of the tree at its top faster than it comes in at the roots. By sunset the air cools off. The evaporation of water from the leaves is lessened and the water pipes inside the tree trunk swell up. The tree is then larger than it was the night before, for some new wood has been formed during the day.

So, when the tree records its daily behavior by tis diary written on the *dendrograph,* its story for each week is a wavy line on a strip of paper a foot long. To the student of trees this line tells as much as if the tree had used hundreds of words. The expert in tree handwriting sees at a glance what the tree did every hour in the week and also knows why the tree did each particular thing.

It may be seen, for example, that it was warm and cloudy on Monday, in consequence of which the tree grew rapidly and strongly; that it rained on Tuesday; that the hot sun on Wednesday caused a very noticeable shrinkage of the trunk on Thursday, which became even greater on Friday when a gentle breeze increased the evaporation of water from the leaves. Or, if such a misfortune befall as that the young leaves of the tree were eaten by animals or were cut off by beetles, this tragedy would be told in unmistakable terms on the tree diary of the *dendrograph.*

Two persons do not tell the story of an event in the same words, and the handwriting of one person is never exactly like that of any

other person. This is true of trees, also. The handwriting of the oak can be distinguished readily from that of the ash, while no pine tree could successfully forge the signatures of a walnut or a maple or a beech.

I have accumulated diaries of several kinds of trees growing in various places in the United States from the Atlantic to the Pacific Oceans. The total of the periods covered by these diaries is now about one hundred and twenty years. If these records were thrown together haphazard in a pile, they could be sorted out again easily by the mere character of the individual writing.

Many things can be learned from these tree diaries. We have not yet studied the growth of trees in the tropics where it is always warm and where new wood may be formed on trees almost every day in the year, but in eastern America the season of growth may not begin until May or June. For most kinds of trees in this region the growth season ends in July or August, but these dates differ somewhat for different kinds of trees. Most trees carry out all their annual growth within sixty to one hundred days, which is about the length of time required for the maturing of the ordinary field crops, like wheat and rye.

THOMAS ALVA EDISON
and the tablet erected in his honor by the Edison Pioneers at Menlo Park, N. J., where Mr. Edison lived and had his laboratory from 1876 to 1882 at the time that the incandescent lamp was invented by him.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

THE CENTENARY OF BENZENE

JUNE 16 is the hundredth anniversary of an epoch-making event, the opening of a new era of civilization. Yet it will pass unnoticed by the multitude that enjoy its benefits. They will go about their business and pleasure as usual; driving motor cars over roads made smooth by coal-tar and level by explosives; they will listen to the music of the phonograph or radio; they will wear gaily colored clothing, enjoy pleasant perfumes and aromatic flavors and ward off disease by drugs and ointments without giving a thought of gratitude to the modest man who a hundred years before discovered the mother substance of these comforts, conveniences and luxuries of modern life, that is, benzene.

For this is one of the silent revolutions of science, originating in a most unspectacular event, plain Michael Faraday, the blacksmith's son, working in the basement laboratory of the Royal Institution in London, separating out from compressed oil gas a few drops of a clear colorless limpid liquid, giving no hint of the potent poisons, brilliant dyes, pungent scents and high explosives that are derived from it.

Benzene is a key compound, we may call it a key-ring compound, for when the chemist draws a diagram of its molecule on the blackboard he makes a ring or hexagon of six carbon atoms, holding hands like half a dozen children playing ring-around-rosy. That is why it gives a chance for so many derivatives. The chemist can attach any kind of atom, or group of atoms, to any of the six carbons and while it makes no difference which of the six he attaches the first side-chain to, it does make a difference where he attaches later side-chains. The chemist has made about 150,000 compounds on the basis of the benzene ring in the century since Faraday discovered it, and he can make as many more if he needs them in his business. All these derivatives are distinct and different, as different as a cat and dog, or as a pot of poison and a pork pie. Most of them are novelties, creations of the chemist, not found in nature. The benzene compounds have added immeasurably to the wealth of the world, to the length of life and to the joy of living.

But the man who first made benzene died poor. He might have made half a million dollars or more if he had turned his talents to commercial work. But he preferred to be a pioneer, and he deliberately set aside the temptations of wealth and title, and devoted his life to the pursuit of pure science. His professional business income during the later and most fruitful years of his life ranged from $500 a year to zero.

Such a man, whose labors contribute to the enrichment of his country and the world at large, instead of to his own profit, should be supported by the nation, but when Faraday was persuaded to apply to the government for a pension, so he could continue his researches in electricity and chemistry, Lord Melbourne, the prime minister, laughed at him and called him a humbug.

But the world knows him better now than did his rulers, and few will be disposed to dispute the judgment of his friend and collaborator, Tyndall, who said that "Michael Faraday was the greatest experimental philosopher that the world has ever seen."

Faraday announced his discovery of benzene to the Royal Society of London on June 16, 1825, and on that date this year delegates of the chemical societies and chemical industries of Great Britain and the United States assembled at the Royal Institution at London to do honor to this great man and to appraise the value of his discovery to the world.

FOOD FROM SHALE

The oil shales with which our country is so abundantly supplied may some day in the far future come into play to help out our failing food supply as well as our dearth of gasoline. The problem has already passed from the question of possibility to the question of profitability. The chemist is confident that he can make edible fats from shale oil, but he can not yet compete with the cottonseed or the hog.

In fact, the chemist has now up his sleeve processes for making fats from almost any kind of carbonaceous material: coal, lignite, petroleum, wood tar, sawdust and other unappetizing stuff. He can not only make the scores of fats and oils that are found ready made in plants and animals, but he can make hundreds of others that nature never thought of. And those that he has most recently patented prove to be just as nutritious as those that the human race has been living on for the last hundred thousand years or so.

The reason why the chemist can make synthetic fats in such variety is because they are all built on the same simple structure, a long chain of carbon atoms, hand in hand like the chains of paper dolls that we used to cut out of a folded newspaper. Each carbon has two hydrogens attached on the side, except one of the end ones which carries two oxygens. This is what is known as a "fatty acid" and there is a large family of these fatties. All those found in nature have very oddly an even number of carbons in the chain, but the chemist can make the missing odd members that come in between, and so complete the series. The most common fats and oils, such as butter or lard, olive or peanut oil, consist mostly of various mixtures of those members of the family having 14, 16 or 18 carbons in the chain. These are combined with glycerine in the fat foods, but if you substitute sodium for the glycerine, which you can easily do by adding lye—your great grandmother knew how if you don't—you will get a soap.

Now tar, petroleum, shale oil and other mineral oils consist of similar carbon chains, but lacking the oxygen-tipped end which makes the acid. Often indeed the chain has no end, for it is hooked up into a ring. But the chemist has discovered that he can introduce the oxygen by driving hot air through the mineral oil, or by using that concentrated and active form of oxygen as "ozone." The combination may be aided by high pressure and by the presence of some heavy metal, such as manganese, lead or mercury, that acts as a catalyst or carrier for the oxygen. After the oil is cracked up and oxidized by such means, alkali is added and soap is produced. The yield is poor and the process is expensive, but proffer enticing possibilities of future development. In Germany much has been

accomplished in this field, and in the United States many chemists are actively engaged in cracking up petroleum to produce various useful products. What they have found out will not be revealed to the public until it has been whispered into the ear of the Commissioner of Patents, but it is known that they have found it possible to get, not only a greater yield of gasoline, but also fatty acids, and a lot of alcohols and other oxidation products, that are much in demand of late for the new lacquer solvents.

But supposing we can get cheap fatty acids from coal or mineral oils, where can we get the glycerine that is necessary to combine with them to form edible food? To rob the natural fats of their glycerine to add to our synthetic fats would not get us ahead any. One solution to this problem is the discovery that glycerine may be made by fermentation from sugar or molasses. During the war a thousand tons a month were made by this method in England where glycerine was needed in large amount to make nitroglycerine.

But there is another possibility that I will only hint at in closing since it may be regarded as chimerical. These fatty acids will unite not only with glycerine but also with the sugars and starches. This would add to their nutritive power, for such a food would give at once the fats and carbohydrates essential for diet; butter and potatoes, not merely on the same plate, but in the same molecule. How such a synthetic food would taste I don't know, but doubtless the chemist could fix up the flavor to suit.

MOONSHINE MORPHINE

The offer of a $100,000 reward by Herman A. Metz for the discovery of a process for the cheap manufacture of synthetic morphine calls public attention to the possibility that the chemist may at any moment upset the best laid plans of legislators and financiers, as he has often done before. If the Metz prize, or the still greater pecuniary profits of the process, should instigate such a discovery, the elaborate schemes of tariff regulations and the complicated negotiations for international control would at once become futile.

The opium crop of India might be wiped out as was the indigo crop by the discovery of synthetic indigo in 1902. The British conscience would be relieved of the temptation to maintain an open opium market which caused Great Britain in 1840 to make war on China, and which induced her to block the recent attempts of the League of Nations to suppress the traffic.

If the habit-forming drugs may be made anywhere by anybody who knows how, the question ceases to be an international issue and becomes a matter of local police powers. But then the difficulty would arise of how to prevent illicit manufacture. If the synthetic process were publicly known and simple to carry out, it would be harder to prohibit or to regulate than alcohol, because the drugs are easier to conceal and smuggle and the profits are larger. Morphine and cocaine sell for about $175 a pound, and if they could be made cheaply from chemicals easily procurable, there might arise a thriving industry—or rather business—in moonshine morphine and contraband cocaine.

Although the number of drug addicts in the United States has decreased since the passage of the Anti-Narcotic Act, there are between 100,000 and 150,000 according to the estimates of the U. S. Public Health Service. So there is still a market for the illicit traffic, but we may hope

that the manufacture of such drugs artificially, when we learn how to do it, may be so centralized in a few factories that it may be kept under close supervision. Possibly the patents could be put under the control of the League of Nations or of the Narcotic Committee of the International Police Conference.

The offer of the $100,000 prize indicates that a satisfactory method of making synthetic morphine is yet unknown to the public, though some chemist may come forward any day with the formula.

Heroin, which according to the New York Police reports is used by ninety-four per cent. of the criminal drug addicts, is not a natural product but a synthetic compound, being made by the action of acetic acid on morphine. But morphine has so far been prepared from opium which comes from the juice of poppy pods. The morphine molecule is very complicated and its structure is not certainly known.

Synthetic cocaine is a more practicable proposition and has in fact been actually accomplished. Professor Richard Willstaetter, of Berlin, has worked out three different ways of making alkaloids of the cocaine family, one of which "psicain" is claimed to be a stronger local anesthetic than the natural. Professor Julius von Braun, of Breslau, has been working on the same problem for the last ten years. The synthetic products usually differ from that extracted from the coca leaves. The natural twists a ray of polarized light to left while the artificial is apt to be neutral. Their physiological action may be different also. But on October 31, 1923, a British patent was taken out for the manufacture of left-handed cocaine, identical with the vegetable product.

The primary materials used in making synthetic cocaine are mostly cheap and common chemicals; one of them is citric acid, the lemon acid; another is ammonium chloride, our familiar "sal ammoniac"; and a third is formaldehyde, the household disinfectant.

Several synthetic substitutes for cocaine, such as novocaine or procaine, have come into use, since they are quite as effective and are not habit-forming. Some day, we may be confident, the chemist may find out how to make these useful but seductive drugs, but by that time he may be making other compounds superior to the natural.

ARTIFICIAL FOOD

THE other day Secretary Hoover, in referring to the new German process for making methanol and formaldehyde directly and cheaply from coal and water, suggested the possibility that the chemist may some day be able to make synthetic food.

The first and fundamental question is whether food can be made from earth, air and water. Anybody can answer that question as well as a chemist, for all our food is now made from earth, air and water.

The real questions are: Will man ever be able to manufacture his own food? Must he always be dependent upon the plants for his provender?

These are not so easily answered because food is of various sorts and some are easier to produce than others. As everybody knows now-a-days there are five classes of compounds essential to every well-balanced diet. There are: first, salts; second, fats; third, carbohydrates; fourth, proteins; fifth, vitamins. I put them in this order because this is the order in which the chemist is conquering them.

The first, the mineral matter, is already conquered, for the chemist can make any kind of salts he wants, and he now knows what kinds he wants.

JOHN T. SCOPES

Teacher in the high school at Dayton, Tennessee, who has submitted to a trial to test the constitutionality of the law forbidding the teaching in state-supported institutions of "any theory that denies the story of the divine creation of man as taught in the Bible, and to teach instead that man has descended from a lower order of animals."

"FOR I'M THE LORD HIGH EXECUTIONER

Courtesy of The New York World

The second food constituent, the fats and oils, can also be struck off the list, for the chemist could make any of them out of coal and water if he had to, though he would hate to have to for it is a tedious and expensive process and he would starve before he got enough to butter his bread or dress his salad. He can not only imitate nature in making any of the fats found in plants and animals, but he can make new ones that nature never thought of. I have on my desk a quarter pound of such a synthetic fat, glyceryl margarate, the chemist calls it, that is altogether an artificial compound, yet it is as nutritious as tallow or lard.

The third class, the carbohydrates, comprises a variety of starches and sugars and similar substances. They are very complicated compounds of carbon, hydrogen and oxygen and their structure has only recently been unraveled. The simplest possible compound of these three elements is that containing one atom of carbon, one of oxygen and two of hydrogen. This is formaldehyde, the irritating gas used as a disinfectant under the name of formalin. Now if you multiply the formula of formaldehyde by six you get the simplest of the sugars, glucose. This multiplication of the molecule is easy to do on paper, but if you try to do it in the laboratory you will find it tremendously difficult. Hundreds of chemists have worked

BACK TO THE INQUISITION.

Courtesy of The New York World

at the problem and only a few have succeeded and these to only a limited extent. Last summer at the Toronto meeting of the British Association for the Advancement of Science, Professor E. C. C. Baly, of the University of Liverpool, exhibited a bottle of syrup which he had made by exposing a solution of formaldehyde in water to the ultra-violet rays from a quartz mercury lamp for weeks. This had been analyzed by Principal Irvine, of St. Andrew's University, Scotland, and found to contain some ten per cent. of glucose and sugars of similar sort. Principal Irvine at the same meeting announced the synthesis of a starch, which is a still more complicated compound, for starch breaks down into glucose. So it is evident that there is no insuperable barrier to the artificial manufacture of these two forms of food from which we derive most of our muscular energy. But to get even the small amount of sugar that Professor Baly made required enormous expenditure of electrical energy, and it was not fit to eat at that.

To produce the fourth class of food ingredients, the proteins, is much more difficult than the preceding because their structure is more complex and varied, and a variety of them is essential in any diet. One kind of

sugar can replace another and all the fats are likewise interchangeable. We can even get along without sugar if we have fat, and *vice versa.* But we not only have to have some protein in our food but we have to have several particular kinds. A protein molecule may embrace a sugar molecule and will also contain certain compounds containing nitrogen which are called the "amino acids" because they are related to ammonia. There are some eighteen amino acids found in food, but they may not all be essential. Perhaps we could get along on a dozen or less. The constitution of the amino acids is known and they might be made artificially. It has been found on feeding experiments with rats that they will live on a diet without protein if they are fed with the proper kinds of amino acids. That is, they can construct the proteins of their body out of the building blocks of amino acids. So we may not need to go so far as the complete protein to get synthetic food.

The fifth food factor, the vitamins, is still far beyond our reach. We know there are several substances that are essential for any dietary in minute amounts, but we do not yet know how many there are, nor what they are. They are not even named, but are provisionally labeled A, B, C, D, E, and nobody can tell how much farther down the alphabet they will run. None of the five or more has yet been identified. They are all mavericks so far, but we may expect them to be caught and branded before many years. The latest triumph in this field is the discovery that it is possible to form or at least to activate one of the vitamins, in food that does not contain it, by the action of ultra-violet light. This gives promise that the chemist may be able to make them whenever he finds out just what they are.

This then is the situation. Three of the five food factors could theoretically be made in the laboratory, though it may be some time before we make enough of the third to feed a rat. The fourth seems possible and the fifth looks hopeful.

But from test-tube experiment to laboratory production is a long and perhaps unattainable step. Even if we learn how to make the various constituents of our daily diet we shall likely find that in general it will not pay us to do it, for the plants can still make them cheaper than we can.

So to the first question, "Will man ever be able to manufacture his own food?" I would answer "yes." And to the second question, "Must he always be dependent upon the plants for his provender?" I would also answer "yes."

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AUGUST, 1925

THE COMING OF AGE OF THE ORIGIN OF SPECIES[1]

By Professor T. H. HUXLEY

MANY of you will be familiar with the aspect of this small, green-covered book. It is a copy of the first edition of the "Origin of Species," and bears the date of its production—the 1st of October, 1859. Only a few months, therefore, are needed to complete the full tale of twenty-one years since its birthday.

Those whose memories carry them back to this time will remember that the infant was remarkably lively, and that a great number of excellent persons mistook its manifestations of a vigorous individuality for mere naughtiness; in fact, there was a very pretty turmoil about its cradle. My recollections of the period are particularly vivid; for, having conceived a tender affection for a child of what appeared to me to be such remarkable promise, I acted for some time in the capacity of a sort of under-nurse, and thus came in for my share of the storms which threatened even the very life of the young creature. For some years it was undoubtedly warm work, but, considering how exceedingly unpleasant the apparition of the new-comer must have been to those who did not fall in love with him at first sight, I think it is to the credit of our age that the war was not fiercer, and that the more bitter and unscrupulous forms of opposition died away as soon as they did.

I speak of this period as of something past and gone, possessing merely an historical, I had almost said an antiquarian interest. For, during the second decade of the existence of the "Origin of Species," opposition, though by no means dead, assumed a different aspect. On the part of all those who had any reason to respect them-

[1] A lecture delivered at the Royal Institution, Friday, March 19, 1880, and printed in the July, 1880, issue of THE POPULAR SCIENCE MONTHLY, the editorial predecessor of THE SCIENTIFIC MONTHLY.

selves, it assumed a thoroughly respectful character. By this time the dullest began to perceive that the child was not likely to perish of any congenital weakness or infantile disorder, but was growing into a stalwart personage, upon whom mere goody scoldings and threatenings with the birch-rod were quite thrown away.

In fact, those who have watched the progress of science within the last ten years will bear me out to the full when I assert that there is no field of biological inquiry in which the influence of the "Origin of Species" is not traceable; the foremost men of science in every country are either avowed champions of its leading doctrines, or at any rate abstain from opposing them; a host of young and ardent investigators seek for and find inspiration and guidance in Mr. Darwin's great work; and the general doctrine of evolution, to one side of which it gives expression, finds in the phenomena of biology a firm base of operations whence it may conduct its conquest of the whole realm of nature.

History warns us, however, that it is the customary fate of new truths to begin as heresies and to end as superstitions; and, as matters now stand, it is hardly rash to anticipate that, in another twenty years, the new generation, educated under the influences of the present day, will be in danger of accepting the main doctrines of the "Origin of Species" with as little reflection, and it may be with as little justification, as so many of our contemporaries, twenty years ago, rejected them.

Against any such a consummation let us all devoutly pray; for the scientific spirit is of more value than its products, and irrationally-held truths may be more harmful than reasoned errors. Now, the essence of the scientific spirit is criticism. It tells us that, to whatever doctrine claiming our assent, we should reply, Take it if you can compel it. The struggle for existence holds as much in the intellectual as in the physical world. A theory is a species of thinking, and its right to exist is coextensive with its power of resisting extinction by its rivals.

From this point of view it appears to me that it would be but a poor way of celebrating the Coming of Age of the Origin of Species were I merely to dwell upon the facts, undoubted and remarkable as they are, of its far-reaching influence and of the great following of ardent disciples who are occupied in spreading and developing its doctrines. Mere insanities and inanities have before now swollen to portentous size in the course of twenty years. Let us rather ask this prodigious change in opinion to justify itself; let us inquire whether anything has happened since 1859 which will explain, on rational grounds, why so many are worshiping that which they burned, and

burning that which they worshiped. It is only in this way that we shall acquire the means of judging whether the movement we have witnessed is a mere eddy of fashion, or truly one with the irreversible current of intellectual progress, and, like it, safe from retrogressive reaction.

Every belief is the product of two factors: the first is the state of the mind to which the evidence in favor of that belief is presented; and the second is the logical cogency of the evidence itself. In both these respects the history of biological science during the last twenty years appears to me to afford an ample explanation of the change which has taken place; and a brief consideration of the salient events of that history will enable us to understand why, if the "Origin of Species" appeared now, it would meet with a very different reception from that which greeted it in 1859.

One-and-twenty years ago, in spite of the work commenced by Hutton and continued with rare skill and patience by Lyell, the dominant view of the past history of the earth was catastrophic. Great and sudden physical revolutions, wholesale creations and extinctions of living beings, were the ordinary machinery of the geological epic brought into fashion by the misapplied genius of Cuvier. It was gravely maintained and taught that the end of every geological epoch was signalized by a cataclysm, by which every living being on the globe was swept away, to be replaced by a brand-new creation when the world returned to quiescence. A scheme of nature which appeared to be modeled on the likeness of a succession of rubbers of whist, at the end of each of which the players upset the table and called for a new pack, did not seem to shock anybody.

I may be wrong, but I doubt if at the present time there is a single responsible representative of these opinions left. The progress of scientific geology has elevated the fundamental principle of uniformitarianism, that the explanation of the past is to be sought in the study of the present, into the position of an axiom; and the wild speculations of the catastrophists, to which we all listened with respect a quarter of a century ago, would hardly find a single patient hearer at the present day. No physical geologist now dreams of seeking outside the ranges of known natural causes for the explanation of anything that happened millions of years ago, any more than he would be guilty of the like absurdity in regard to current events.

The effect of this change of opinion upon biological speculation is obvious. For, if there have been no periodical general physical catastrophes, what brought about the assumed general extinctions and recreations of life which are the corresponding biological catastrophes? And if no such interruptions of the ordinary course of

nature have taken place in the organic, any more than in the inorganic, world, what alternative is there to the admission of evolution?

The doctrine of evolution in biology is the necessary result of the logical application of the principles of uniformitarianism to the phenomena of life. Darwin is the natural successor of Hutton and Lyell, and the "Origin of Species" the natural sequence of the "Principles of Geology."

The fundamental doctrine of the "Origin of Species," as of all forms of the theory of evolution applied to biology, is "that the innumerable species, genera and families of organic beings with which the world it peopled have all descended, each within its own class or group, from common parents, and have all been modified in the course of descent.[2]

And, in view of the facts of geology, it follows that all living animals and plants "are the lineal descendants of those which lived long before the Silurian epoch."[3]

It is an obvious consequence of this theory of Descent with Modification, as it is sometimes called, that all plants and animals, however different they may now be, must, at one time or other, have been connected by direct or indirect intermediate gradations, and that the appearance of isolation presented by various groups of organic beings must be unreal.

No part of Mr. Darwin's work ran more directly counter to the prepossessions of naturalists twenty years ago than this. And such prepossessions were very excusable, for there was undoubtedly a great deal to be said, at that time, in favor of the fixity of species and of the existence of great breaks, which there was no obvious or probable means of filling up, between various groups of organic beings.

For various reasons, scientific and unscientific, much had been made of the hiatus between man and the rest of the higher mammalia, and it is no wonder that issue was first joined on this part of the controversy. I have no wish to revive past and happily forgotten controversies, but I must state the simple fact that the distinctions in cerebral and other characters, which were so hotly affirmed to separate man from all other animals in 1860, have all been demonstrated to be non-existent, and that the contrary doctrine is now universally accepted and taught.

But there were other cases in which the wide structural gaps asserted to exist between one group of animals and another were by no means fictitious; and, when such structural breaks were real Mr.

[2] "Origin of Species," first edition, p. 457.

[3] "Origin of Species," first edition, p. 458.

Darwin could account for them only by supposing that the intermediate forms which once existed had become extinct. In a remarkable passage he says: "We may thus account even for the distinctness of whole classes from each other—for instance, of birds from all vertebrate animals—by the belief that many animal forms of life have been utterly lost, through which the early progenitors of birds were connected with the early progenitors of the other vertebrate classes."[4]

Adverse criticism made merry over such suggestions as these. Of course it was easy to get out of the difficulty by supposing extinction; but, where was the slightest evidence that such intermediate forms between birds and reptiles as the hypothesis required ever existed? And then probably followed a tirade upon this terrible forsaking of the paths of "Baconian induction."

But the progress of knowledge has justified Mr. Darwin to an extent which could hardly have been anticipated. In 1862 the specimen of *Archæopteryx*, which until the last two or three years has remained unique, was discovered; and it is an animal which, in its feathers and the greater part of its organization, is a veritable bird, while, in other parts, it is as distinctly reptilian.

In 1868 I had the honor of bringing under your notice. in this theater, the results of investigations made, up to that time, into the anatomical characters of certain ancient reptiles, which showed the nature of the modifications in virtue of which the type of the quadrupedal reptile passed into that of the bipedal bird; and abundant confirmatory evidence of the justice of the conclusions which I then laid before you has since come to light.

In 1875 the discovery of the toothed birds of the cretaceous formation in North America, by Professor Marsh, completed the series of transitional forms between birds and reptiles, and removed Mr. Darwin's proposition, that "many animal forms of life have been utterly lost, through which the early progenitors of birds were formerly connected with the early progenitors of the other vertebrate classes," from the region of hypothesis to that of demonstrable fact.

In 1859 there appeared to be a very sharp and clear hiatus between vertebrated and invertebrated animals, not only in their structure, but what was more important, in their development. I do not think that we even yet know the precise links of connection between the two; but the investigations of Kowalewsky and others upon the development of *Amphioxus* and of the *Tunicata* prove beyond a doubt that the differences which were supposed to constitute a barrier between the two are non-existent. There is no longer

[4] *Ibid.*, p. 431.

any difficulty in understanding how the vertebrate type may have arisen from the invertebrate, though the full proof of the manner in which the transition was actually effected may still be lacking.

Again, in 1859 there appeared to be a no less sharp separation between the two great groups of flowering and flowerless plants. It is only subsequently that the series of remarkable investigations inaugurated by Hofmeister has brought to light the extraordinary and altogether unexpected modifications of the reproductive apparatus in the *Lycopodiaceae*, the *Rhizocarpeae*, and the *Gymnospermeae*, by which the ferns and the mosses are gradually connected with the Phanerogamic division of the vegetable world.

So, again, it is only since 1859 that we have acquired that wealth of knowledge of the lowest forms of life which demonstrates the futility of any attempt to separate the lowest plants from the lowest animals, and shows that the two kingdoms of living nature have a common border-land which belongs to both or to neither.

Thus it will be observed that the whole tendency of biological investigation since 1859 has been in the direction of removing the difficulties which the apparent breaks in the series created at that time; and the recognition of gradation is the first step toward the acceptance of evolution.

As another great factor in bringing about the change of opinion which has taken place among naturalists, I count the astonishing progress which has been made in the study of embryology. Twenty years ago, not only were we devoid of any accurate knowledge of the mode of development of many groups of animals and plants, but the methods of investigation were rude and imperfect. At the present time there is no important group of organic beings the development of which has not been carefully studied, and the modern methods of hardening and section-making enable the embryologist to determine the nature of the process in each case, with a degree of minuteness and accuracy which is truly astonishing to those whose memories carry them back to the beginnings of modern histology. And the results of these embryological investigations are in complete harmony with the requirements of the doctrine of evolution. The first beginnings of all the higher forms of animal life are similar, and, however diverse their adult conditions, they start from a common foundation. Moreover, the process of development of the animal or the plant from its primary egg or germ is a true process of evolution—a progress from almost formless to more or less highly organized matter, in virtue of the properties inherent in that matter.

To those who are familiar with the process of development all *a priori* objections to the doctrine of biological evolution appear

childish. Any one who has watched the gradual formation of a complicated animal from the protoplasmic mass which constitutes the essential element of a frog's or a hen's egg has had under his eyes sufficient evidence that a similar evolution of the animal world from the like foundation is, at any rate, possible.

Yet another product of investigation has largely contributed to the removal of the objections to the doctrine of evolution current in 1859. It is the proof afforded by successive discoveries that Mr. Darwin did not over-estimate the imperfection of the geological record. No more striking illustration of this is needed than a comparison of our knowledge of the mammalian fauna of the Tertiary epoch in 1859 with its present condition. M. Gaudry's researches on the fossils of Pikermi were published in 1868, those of Messrs. Leidy, Marsh and Cope on the fossils of the Western Territories of America have appeared almost wholly since 1870; those of M. Filhol, on the phosphorites of Quercy, in 1878. The general effect of these investigations has been to introduce us to a multitude of extinct animals, the existence of which was previously hardly suspected; just as if zoologists were to become acquainted with a country, hitherto unknown, as rich in novel forms of life as Brazil or South Africa once was to Europeans. Indeed, the fossil fauna of the Western Territories of America bids fair to exceed in interest and importance all other known Tertiary deposits put together; and yet, with the exception of the case of the American tertiaries, these investigations have extended over very limited areas, and at Pikermi were confined to an extremely small space.

Such appear to me to be the chief events in the history of the progress of knowledge, during the last twenty years, which account for the changed feeling with which the doctrine of evolution is at present regarded by those who have followed the advance of biological science in respect of those problems which bear indirectly upon that doctrine.

But all this remains mere secondary evidence. It may remove dissent, but it does not compel assent. Primary and direct evidence in favor of evolution can be furnished only by paleontology. The geological record, so soon as it approaches completeness, must, when properly questioned, yield either an affirmative or a negative answer; if evolution has taken place, there will its mark be left; if it has not taken place, there will lie its refutation.

What was the state of matters in 1859? Let us hear Mr. Darwin, who may be trusted always to state the case against himself as strongly as possible.

"On this doctrine of the extermination of an infinitude of connecting links between the living and extinct inhabitants of the

world, and at each successive period between the extinct and still older species, why is not every geological formation charged with such links? Why does not every collection of fossil remains afford plain evidence of the gradation and mutation of the forms of life? We meet with no such evidence, and this is the most obvious and plausible of the many objections which may be urged against my theory."[5]

Nothing could have been more useful to the opposition than this characteristically candid avowal, twisted as it immediately was into an admission that the writer's views were contradicted by the facts of paleontology. But, in fact, Mr. Darwin made no such admission. What he says in effect is, not that paleontological evidence is against him, but that it is not distinctly in his favor; and, without attempting to attenuate the fact, he accounts for it by the scantiness and the imperfection of that evidence.

What is the state of the case now, when, as we have seen, the amount of our knowledge respecting the mammalia of the Tertiary epoch is increased fifty-fold, and in some directions even approaches completeness?

Simply this, that, if the doctrine of evolution had not existed, paleontologists must have invented it, so irresistibly is it forced upon the mind by the study of the remains of the Tertiary mammalia which have been brought to light since 1859.

Among the fossils of Pikermi, Gaudry found the successive stages by which the ancient civets passed into the more modern hyenas; through the Tertiary deposits of Western America, Marsh tracked the successive forms by which the ancient stock of the horse has passed into its present form; and innumerable less complete indications of the mode of evolution of other groups of the higher mammalia have been obtained.

In the remarkable memoir on the phosphorites of Quercy, to which I have referred, M. Filhol describes no fewer than seventeen varieties of the genus *Cynodictis* which fill up all the interval between the viverine animals and the bear-like dog *Amphicyon;* nor do I know any solid ground of objection to the supposition that in this *Cynodictis-Amphicyon* group we have the stock whence all the Viveridæ, Felidæ, Hyænidæ, Canidæ, and perhaps the Procyonidæ and Ursidæ, of the present fauna have been evolved. On the contrary, there is a great deal to be said in its favor.

In the course of summing up his results, M. Filhol observes:

"During the epoch of the phosphorites, great changes took place in animal forms, and almost the same types as those which now exist became defined from one another.

[5] "Origin of Species," first edition, p. 463.

"Under the influence of natural conditions of which we have no exact knowledge, though traces of them are discoverable, species have been modified in a thousand ways: races have arisen which, becoming fixed, have thus produced a corresponding number of secondary species."

In 1859, language of which this is an unintentional paraphrase, occurring in the "Origin of Species," was scouted as wild speculation; at present, it is a sober statement of the conclusions to which an acute and critically-minded investigator is led by large and patient study of the facts of paleontology. I venture to repeat what I have said before, that, so far as the animal world is concerned, evolution is no longer a speculation, but a statement of historical fact. It takes its place alongside of those accepted truths which must be taken into account by philosophers of all schools.

Thus when, on the first day of October next, the "Origin of Species" comes of age, the promise of its youth will be amply fulfilled; and we shall be prepared to congratulate the venerated author of the book, not only that the greatness of his achievement and its enduring influence upon the progress of knowledge have won him a place beside our Harvey; but, still more, that, like Harvey, he has lived long enough to outlast detraction and opposition, and to see the stone that the builders rejected become the headstone of the corner.

produced them are tied up in some structural container or carrier, such as a chromosome. Moreover, a statistical study of heredity shows that the "unit characters" of the parents are transmitted to their offspring in definite numerical ratios (Mendelian Law) comparable with the distribution and numerical combination of chromosomes that takes place in the germ cells during the initial stages of sexual reproduction.

Thus in death and sexual reproduction all the great problems of the biologist come to a focus. For living systems renew their life by dying. They grow again by returning in part to the one system that includes them all and which never dies. Special provision is made for this inevitable emergency. That is, some of the cells of the embryo are at once set apart, with little or no change in their initial structure and power of growth, as the germ cells of the new body. When that body has served its purpose and death draws near, all its marvelous machinery operates to set the germ cells free and to provide for them the ways and means for a new and larger life.

The contrasts of sex are but the contrasts in two sets of germinal, bodily and mental equipments, whose common function is to combine their resources and so create a larger and a more varied life. The perpetuation of life and progress depends on the fitness of the whole dual machinery of sex to bring about that result; that is, to bring two different kinds of germ cells into cooperative action, and then to nourish, shelter and guide the new life during its earlier stages of development.

In the preliminary preparations for their union (*maturation processes*) the chromosomes of each germ cell stretch out to great lengths and unite in pairs (synapsis). During this brief period they apparently exchange genes, like two players drawing one or more cards from each other's hands. Then two divisions take place (reducing divisions) the end result being that each mature germ cell or gamete receives about one half the initial number of chromosomes. Any one of the male gametes may then unite with or fertilize a female gamete of the same species and so initiate a new individual.

Thus in the game of life, the maturation processes virtually shuffle the hereditary pack and deal out half a "hand" to each gamete. A full hand is obtained by drawing a partner from the "board" or by combining with some other gamete of the opposite sex. And one of the "hands" always contains a bonus or a "jack pot" of golden yolk that was contributed as an "ante" by one of the players.

Hence offspring resemble their parents because they play the game of life with the same kind of cards, but not however with the same hands. The minor differences in offspring, or the variations from the standard type that always go with these basic resemblances, are due to variations in the distribution of the genes during maturation, fertilization and cleavage.

Thus sufficient stability and variety is produced to insure continuity and progress. For the offspring will in the main resemble those progenitors which have most successfully lived in the prevailing conditions of the past, but will be sufficiently different to insure that some of them shall successfully live in any conditions likely to arise in the future.

The chief purpose of sex and sexual reproduction, therefore, is to bring about this happy combination of stability and variety. For hereditary stability preserves the best of the past, while hereditary variation provides the necessary means for improvement.

Changes in the environments, such as climate, foods, associates, habits, etc., are always accompanied by corresponding changes in the structure and function of the cells that make up the body. But such changes ordinarily have no appreciable influence on the more stable genes and their combinations. Hence these so-called "acquired characters" will not be inherited. That is, they will not reappear in the next generation unless the environmental conditions are much the same as before, or unless the genes themselves have been modified.

Thus plants and animals, males and females, parents and offspring, are clock-like reciprocating mechanisms bound together in one "big union" wherein the gain or loss of one checks or accelerates, for better or worse, all the others. These clock-like mechanisms run with marvellous regularity and precision, partly because of their own activities and partly because they are wound up and regulated by such universal and steadfast agencies as atomic action, light, gravity and electricity.

This rhythmic alternation of bodily death and bodily regeneration has been going on without interruption for untold millions of years. It has produced the life we see to-day and in which we now participate. The heart of that creative process is hidden in the tiny chromosomes of the germ cells, but it takes the whole universe to make it beat and to guide its beating. That, very briefly, is the essence of the modern theory of heredity.

III. Methods, Principles, Virtues

The chromosome theory is now the backbone concept of the biologists. Around this central framework of interlocking facts and

theories circulate all their discussions and about it they are now assembling the more plastic phenomena of life in logical continuity and harmony.

But there are always a few adventurers who immediately ask "How far and where will this or that theory take us?" "What are its limitations?" And they at once "go the limit" in a quick mental test of its larger values. In fact both the peep-hole plodders and the wild-eyed adventurers are always testing the validity of ideas in that way, their "limit" depending on their range of vision and their faith in the "facts" with which their feet are shod.

On some minds the first effect of the modern concept of heredity and evolution has been completely to destroy the old values of life, leaving nothing but bewilderment and despair or the mental vacuum of agnosticism. In others, it has created a blissful faith in democracy and eugenics.

But all of us feel the need of faith in something, and to preserve that faith against assault we must have hard substantial facts to stand on and something tangible with which to test and strengthen the teeth of our beliefs. The cloud-capped altitudes of mystic high-brows are not the citadels of either faith or works. It is only the diggers and hewers of knowledge that can reveal to us the great facts in life and lead us out of the wilderness of little things in which we are entangled.

Let us follow up the trail of the biologists to their logical conclusions and see for ourselves where they go and what they show us. It may take us a long way from home and we shall have to travel in many excentric circles, large and small. For dynamic logic, like all natural phenomena, is cyclic. But any one who wants to go with me on this adventure may do so. We shall find it easy going if we leave all our superfluous mental baggage behind us and go in our naked commonsense.

Merely to expatiate on the wonders of nature and the uncertainties of life to a lost and starving wanderer is a mournful mockery. Any guide or captain worthy of the name should know his objective and how to get there. His knowledge should be positive as well as negative. Within his own province, he should surely know the right way from the wrong way, and he should exercise the full measure of moral and ethical guidance that belongs to his function. It is for him to dictate what must be done and what must not be done, in order to attain the desired goal.

The central concept of biology has been arbitrarily limited for convenience in presentation and in order temporarily to focus our attention on the more sharply defined body of biologic facts. But

in reality it has no limitations and it by no means contains the whole story of life.

There are other factors, other creative principles or virtues which can not be expressed in such definite structural and functional terms. Nevertheless they must be clearly recognized before we can grasp the larger and truer meaning of life and feel the impact of its logic.

These factors have been given many technical names which usually conceal their real meaning. But we shall boldly translate the dialects of science and philosophy into the more familiar terminology of everyday life. We need not be afraid of unduly humanizing what is not human. Fortunately, little enough of us is human. The obvious fact that inanimate and unintelligent things do act in accordance with these principles in no wise invalidates the principles themselves nor diminishes their significance. Indeed it should make them all the more significant to those who call themselves intelligent.

The chief difference between say an atom, a worm and a human being is that man has become more or less conscious of these creative principles or virtues and is "willing" to make some sacrifice of his own resources, bodily or otherwise, in order rightly to use them. Inanimate and unintelligent things apparently are not conscious of them and do not use them "willingly."

Discipline

All environments, great or small, have a dual influence on life that is disciplinary in methods and results. For they compel the living clocks and all their parts to run in certain ways and prevent them from running in certain other ways. Indeed every single thing in nature, great or small, living or dead, is subject to a directive discipline that may be expressed in the familiar terms: Thou shalt. Thou shalt not. Thou mayst. That is why there is law and order and mechanism in life and nature. That is why some things are possible and others impossible.

Work, Mutual Service, Cooperation, Anabolism

No clock, living or otherwise, can be made without labor. Neither can it "run" when it is made without the expenditure of some kind of work or service. Some "inside work" must be done to keep the parts together and to do the running. And some "outside work" must be done to bring the parts together in the first place and to provide them with opportunities to work and with the necessary power to do it.

Such a dual system of "inner" and "outer" service, supply and demand, is essential to the construction and existence of anything. For no one thing, proton or electron, plant or animal, sun or satellite, can do any work all by itself. It must have something to pull or push against, and it must be pushed or pulled by something else. So all nature's work is cooperative work, and before any work whatever can be done, the workers must be mutually serviceable for the doing of that work. Therefore whatever things exist is, in itself, conclusive evidence that such services have been and still are performed. In chemical and protoplasmic domains, the biologist calls this upbuilding or constructive work anabolism.

Usage, Destruction, Sacrifice

But to do anything, something must be "used up" in doing it. That is, something must be diverted from its former state, remodeled, destroyed or sacrificed, before it can serve in whole or in part for the doing of something else. The biologist calls this preliminary breaking down and diversion of chemical power and materials for vital usage katabolism. All previously engaged materials and power must be liberated and redistributed in some such ways before they can be utilized in any other constructive process.

Life, Business, Exchange, Metabolism

This rhythmic down-breaking and upbuilding of bodily structures, together with the circulation of necessary working materials and power between producers and consumers, is called metabolism. To the biologist, it is the surest evidence of life, both in the simplest bits of protoplasm where all other evidence of life is lacking, and in the highest animals where all the bodily functions and organs so obviously collaborate in this vital business.

In the larger circles of human affairs, the whole complex of making, transporting, using and exchanging the commodities of life is called business and, to a "business man," it is the surest evidence of social life. He sees in all this producing and consuming, supplying and demanding, the ways and means by which the human participants "make a living" and, like the biologist, he measures that "business" by the ebb and flow of the accompanying activities and the rates of exchange.

In nature every "unit," large or small, living or dead, is a worker. It is both an actor and a reactor, a producer and a consumer, a center of supply and a center of demand. It is a part, but an inseparable part, as we all are, of that universal working we call nature-action. We act with and react to other workers. That is how and why we "feel" them; and by that compelling evidence we

become aware of their existence. And so in all the operations of nature that directly or indirectly make a sensory appeal to us, in all the phenomena of transformation, circulation and exchange, whether on the stupendous scale of the heavenly bodies or the infinitesimal scale of protons and electrons, we "feel" the evidence of these operations of nature and finally become conscious of that universal business whereby the ways and means of creation are prepared and duly delivered to all her workers.

Profits, Heritages, Benevolence

But in any growing business there must be something more than a flat exchange of values. There must be some gain or profit in the transactions by means of which the business can better carry on and enlarge its undertakings. But before there can be any betterment in service, better ways and means of working must be provided for the workers to work with. That is, something must be transmitted in the nature of a gift, heritage or endowment from the old to the new. Hence something essentially like what we call benevolence or altruism is an indispensable factor in every phase of creative progress. It is the way all profits must be utilized before continuous life and growth can be insured.

It is obvious that the whole purpose of the chromosome mechanism of inheritance is the transmission of the gains of life, in the compact form of germinal structures, to other individuals that are in a condition to make further or better use of them. In return, all the bodily powers of the inheritors are utilized in a lifelong effort to supply these germinal trust funds with sustaining foods and in striving to protect and guide them in the further performance of their functions. Because that work has been well done ever since the beginning of life is one of the reasons why the germ cells are immortal and why these trust funds have steadily accumulated in creative values.

But this reciprocating system of parents and offspring can not work in a vacuum. It must have sustaining and directive soils to live and grow in, such as cosmic, terrestrial, social and mental environments and something to provide beforehand these environmental ways and means of living. All that has been duly provided. Hence all these external conditions that life is heir to are but larger kinds of heritages which, like all heritages, have been created by the labor and sacrifice of the past and made available for present and future uses. They are the larger factors that drive life onwards and upwards and which broadly direct and regulate every phase of germinal and bodily life, human or otherwise.

Variation Freedom

But although nature-action is always lawful and orderly, it is never rigidly mechanical or unyielding, otherwise improvements would be impossible. Every part, organ or individual and all their environments change in some respects from time to time. Hence there is always a certain degree of flexibility, a narrow zone of freedom within which departures from the usual modes of procedure are possible without disaster. When those departures occur, say in an atom, the sun, a plant or animal, or in any of their parts or organs, we speak of it as some intrinsic variation of the thing itself, either in its structure or behavior, or both.

In respect to human affairs, this zone of permissible variation is called freedom. But that freedom is always checked or limited by those environmental conditions on which the very existence of human life depends. To go beyond those shadowy limits into abnormal bodily structure, thought or behavior cuts down the opportunities of life in some respects and always destroys those who go too far.

But within those prescribed limitations there is full freedom of action, with countless inviting opportunities to rest, play, adventure and explore. That freedom to seek and try new ways of doing things, that open road to trial and error, is essential to human progress, to happiness and the hope of still better things. It is a universal heritage, the most precious of all heritages, to inanimate as well as animate things.

The Selective Law

Thus for the very reason that there is both rigidity and flexibility in the order of the universe, there is freedom and compulsion, restraint and opportunity, reward and punishment. That is, there is a dual selective process in perpetual operation which on the one hand favors with further opportunities whatever things are mutually adaptable and mutually serviceable, and which handicaps or destroys those that are not. The result is an increasing degree of rightness in the universe for the accomplishment of whatever end or goal or purpose there may be to accomplish.

This may be expressed in more explicit terms as follows. If any part or organ or thing is better fitted to give help and receive help, it will last longer and create bigger or better things in accordance with the degree of help or service performed. The less helpful things are soonest eliminated, corrected or destroyed. This two-edged justice, which does not permit the over-monstrous to endure, and which favors the more righteous with further life and opportunity, is called the selective law. That is why nature is so fittingly

or adaptively organized. That is why there is art and beauty in nature and ever-widening cycles of creative accomplishment.

Rightness

Because of this inherent flexibility in nature-action, perfection in structure or behavior is unattainable. The approach to perfection only makes perfection recede in the new order thereby created.

The biologist estimates progress in terms of orienting tropisms, or in terms of adaptive adjustments in bodily structure and behavior to the great environmental agencies (such as light, gravity, soils, water and air) in which they live and have their being, and to other living things with which they are associated. That is the only way they can "make progress" or accumulate vital profits.

The measure of that profit or progress is not merely the volume and elaboration of life individually or socially, but the rightness of these functional adjustments in themselves as a means of creation or present existence, and also their rightness as a means for still higher achievements in the future.

In man, there has been added to these more basic tropisms what may be called mental tropisms or the adaptive adjustments of bits of knowledge and ideas to one another (subjectively) and to what actually goes on in the world about him (objectively). These mental corrections of a dawning or growing intelligence provided him with new mental light or new vistas of the creative process, and with them came new power or new sets of compelling motives which sooner or later were expressed in his behavior.

Thus the value of knowledge or wisdom or intelligence depends on its rightness or trueness and on the creative profits that spring from its usage. For instance, when we observe human beings at work or play, we are apt to think there is something right or wrong in it, according to our ideas of the fitness or unfitness of things in general or what we think ought or ought not to be done. And when we look beyond human affairs and observe what is going on in the larger world of nature all about us, we see that things are often done in a shockingly different way from what we expected or believed was right. That makes us want to reform the world so that it will better fit our own ideas and our own convenience.

But when we look a little longer and more thoughtfully, we discover that nature, in her big, slow and methodical ways, is always doing something and is always getting better or larger creative results. And so we can not avoid the conclusion that after all, her ways must be the real ways, the true ways, the right ways, that we are all seeking to discover and to utilize. That makes us want to know still more about them, so that we can better obey them or imi-

tate them or adjust our ways to them and thereby live more profitably.

These mental tropisms of man, as in the architectural (triaxial system) and behavioristic tropisms in plants and animals, are internal adaptive responses to compelling agencies that are external and superior to life. In that superior power is the source of man's truth-seeking spirit and his spirit of service. It is the source of his faith and his hope of better things, whether it is the faith of the scientist in the immutability and justice of natural laws, the faith of the statesman in social institutions, or the faith of a child in its parents or its God.

Thus man's insatiable hunger for knowledge is not a sterile appetite to be fed on facts and satisfied by fruitless thinking. Nor are his artistic longings mere playthings to be spent on fantastic imaginings. These compelling desires are fruitful creative agencies whose purpose is to make men *do* something that sooner or later can be cashed in serviceable realities. For the fruit of thought is service. And service generates purpose. It gives direction and effectiveness to thought and dignity to work, and *that* makes life worth living.

Progress Purpose

There are as many different kinds of progress as there are things done and undone. And since the doing of anything always upsets the previous state of supply and demand between the giver and receiver, producer and consumer, "disturbance of interests" and conflicts of opinion in regard to them inevitably arise, depending on what is done, how it is done and what things are used in doing it. For example, in the making of a pile of bricks or in the unmaking of that pile by moving them to some other place, our estimates of purpose and progress largely depend on whether our own bricks are rightfully moved to the right places in our own buildings, or by a child to the middle of the parlor floor. And in the making and unmaking of a molecule, a cell, a city or a star, or in the moving of a professor from one institution to another, or a flea from one dog to another, our estimates of purpose and progress largely depend on our vested interests in what is used and whose dog or what institution is the beneficiary.

The rhythmic sequence of factors in the accomplishment of anything may be concisely stated as follows: (1) The right (2) using (3) of something (4) for making (5) something else—(1) which (2) is then fit or right (3) for use (4) in making (5) some other thing, etc. Thus the chief factors in any one "element of progress" are rightness, usage and the making or doing of something that is useful. When many such elements follow one another consecutively or methodically that method is evidence of some purpose in the doing of that which is accomplished by it.

In nature there is an infinite number and variety of makings and unmakings with the conveyance of the right materials and power from one time and place to another for their accomplishment. All of them are progressive and purposeful in character and all of them are methodically used in the making of what we call evolutionary progress. Evolution, therefore, is conclusive evidence that there is one grand strategic purpose in all these elementary purposes.

Unchanging Principles and Changing Values

Thus something essentially like what we call discipline, freedom, service, self-sacrifice, benevolence and purpose are indispensable factors in every phase of life, heredity and evolution. Indeed such moral and ethical principles, methods or virtues, it matters little what we call them, are essential prerequisites to the existence and accomplishment of anything. They are immortal or unchangeable, and so axiomatic, so obviously productive of "results," that the most primitive people have not failed to observe them and, more or less consciously, have crudely tried to imitate them in order to obtain the results they most desired. Hence they constitute the basic principles of the oldest systems of social government, ethics and morality, science and religion, of mankind. Then, ignoring his racial achievements and his methods of achievement, man vainly assumes that these virtues are purely human inventions and that he is the only one that uses them!

But when we try to "explain" anything or to discover the particular cause or causes of any one event, we find ourselves utterly unable to do so. The causes of any one event are infinite in number and variety; some are immediate, others more remote and others have their source in the very beginning of all things. Since we can not know all the factors in any one event, however elementary it may be, we never can measure the value of that event, or any one of the factors that caused it, even if all our instruments and methods were perfect, which of course they never can be.

No wonder there is confusion and disagreement among men whenever any one, however learned he may be, tries to explain this or that event in terms of time, space, numbers or energy. They never can be explained in such terms because the creative value of the things themselves is changeable and because there is always an unknowable remainder that is bigger than all the knowable ones put together. Moreover, the one strategic purpose, end or goal that determines all values is a secret no man can know.

The best we can do is to make some tentative explanation, or form some temporary judgment based on the fulness and the radius of our sphere of knowledge. But in making and weighing those

judgments we always use these fundamental virtues as our standards of measurement because, consciously or unconsciously, we have learned that they are the invariable attributes of all causes. In other words, these virtues are in themselves conclusive evidence of that one cause of all things that we call God.

* * *

With the rapid growth of knowledge and the spirit of inquiry, especially during the last century or two, the logical necessity for some unity of method and purpose in natural laws became more and more apparent, not merely to coordinate and vitalize the vast accumulation of incoherent facts, but to reveal their deeper and more religious significance. Strangely enough, when that revelation came, it was celebrated more as a funeral than a birth, as the oncoming of a night of chaos, not as the dawning of a new day. And the spiritual light of evolution went out in mental rioting over trivialities and a bitter struggle for leadership and authority between the partisans of the old and new beliefs.

During that dismal period, whose clouds still hang over us, the old formulas lost their convincing logic, and with it their motive power. The new formulas had no moral or ethical compulsion, no objectives beyond thinly disguised selfish interests. And the new leaders had nothing better to offer than a futile struggle for existence between sheer physical forces and shallow wits.

But with no convincing and therefore compelling authority to guide it, nothing external to work with and for, there can be no rational motive in life. And a self-centered life is automatically suicidal. Thus science, religion, art and politics inevitably degenerated into empty absurdities without unity in language, thought, method or purpose. There was nothing on the horizon of hope to work for beyond the immediate pleasures and necessities of life, and even life itself seemed unnecessary. And then came the penalty!

Now, in calmer moments and with surer knowledge, the inevitable logic of events again directs our judgments. Our clarified vision reveals an unending vista of creative progress. Its records are written in every fiber of nature, root and branch, for all that care to read them, and the God-like methods by which it was accomplished are everywhere manifest.

The logical impact of that revelation is irresistible. Life again is beautiful and pregnant with hope. For nature, the bridegroom of life, has renewed its promise and reaffirmed its guardian purpose. We know the creative way, the way of the old familiar virtues, of discipline and freedom, of mutual service, sacrifice and benevolence, of truth, understanding and righteousness; and we know that in those ways we may live and grow as our heart desires.

EVIDENCES FOR EVOLUTION

SCIENCE SERVICE, WASHINGTON, D. C.

NEW TYPES OF LIFE

By Dr. C. B. DAVENPORT

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THE fundamentalist complains that his faith and that of his children is being shaken by the discoveries and conclusions of the biologist. This faith is based on the teaching, directly or indirectly, of the clergy whose statements the fundamentalist accepts as truth. The biologist has a faith also which is very precious to him and that faith is based on observation of nature and the experimental study of nature's phenomena, and for him the answers that nature gives to his questions are more significant than the assertions of the clergy.

Fundamentalists accept what they have been told about the accuracy of description of the origin of the universe given in the Scriptures. The biologist will accept the authority of no man, not even the man who presumes to state that the description of the origin of the world in the Bible is the "word of God." The biologist has his own idea of what is the word of God. He believes it to be the testimony of nature. This testimony has to be wrung, as it were, out of nature, but in this way evidence can be secured and has been secured that is incontrovertible.

Among the many lines of evidence, one of the most significant is that derived by the study of the origin of new forms under domestication. All kinds of organisms were not made at the beginning of the world. There are now thousands of forms of animals and plants that reproduce their kind which did not exist a century ago. Within the last ten years there have been produced scores of forms of the banana fly never before seen by the eye of man. Indeed, the very day on which the ancestors of some new types first appeared is known and many of these types have persisted to the present day.

We know indeed not a few forms which have appeared recently and which fulfil the essential conditions of species as the naturalist finds them in nature. These forms differ by two or more constant traits from other species. They are quite as infertile with other species as some wild species are with each other. The principal difference between them and wild species is that their beginnings have been seen and are known to be recent while that of wild species has

not been seen and so their origin is of unknown date. But it is known that thousands of wild species that we have on earth to-day did not exist in earlier geological ages, just as there are thousands of species that lived in past geological ages that are not living to-day.

The conception of a world that does not change is one that may have seemed possible to monks shut in their cells; but every one who has traveled and observed widely knows that the face of the earth is changing; and every one who has lived with and bred animals and plants knows that they too are changing.

VARIATIONS AND MUTATIONS

By Dr. VERNON KELLOGG

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When any kind of animal or plant produces offspring these young resemble their parents—but never exactly. There are always differences; lesser or greater. These differences are called variations.

Most of these variations are mere fluctuations around a mean and are not necessarily repeated in the next generation. Some of them, which may be more marked, are undoubtedly due to varying environmental influences and also are not repeated in later generations unless these generations are reared under the same kind of environment.

But sometimes some of these variations reappear in the next and all the succeeding generations, even though the environment surrounding the development of these succeeding generations is not the same as that which surrounded the first generation in which the variations appeared. Such variations are inherited. They breed true.

Such heritable or fixed variations are called mutations, meaning that from one kind of plant or animal a new kind has been produced by a persisting change or sudden little jump. This is the production of a new kind of animal or plant. This is species-forming by mutation. It is the easiest kind of origin of species to observe. It has been observed by many naturalists. These naturalists have seen evolution actually happening.

A kind of little fly, called fruit-fly, which has been very carefully studied for several years by various naturalists, chief of whom is the American zoologist, Professor T. H. Morgan, of Columbia University, has given rise, under their eyes, to many mutations. These are new kinds of fruit flies. Most of them are not kinds better fitted for existence than the original kind of fly from which they

arose. But some are sufficiently fit to persist. They can hold their own in the struggle for existence. They are new additions to the kinds of fruit-flies. They are visible evidences of the present-day evolution of animal kinds.

Similarly, botanists have seen new kinds of plants arise by mutations. The most famous cases of this kind are the mutations of the evening primrose, first carefully observed and described by the great Dutch botanist De Vries, of the University of Amsterdam, and later observed and studied by German, English and American botanists. These new kinds of evening primroses, arising by fixed "jumps" or mutations from a species called Lamarck's evening primrose, are visible evidences of the present-day evolution of plant kinds.

THE EMOTIONS IN MAN AND ANIMALS

By Dr. WILLIAM E. RITTER

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Down to a few years ago nearly all the facts on which rested the hypothesis that man originated from lower forms of life by some marvelous process of natural transformation were drawn from studies on bodily structure. Fossil remains, physical organization of men and other creatures now living and developing embryos were the almost exclusive sources of such facts.

But now that researches into the activities and mental life of all sorts of men, in comparison with all sorts of inferior beings, has been and is being pursued on a vast scale and with great accuracy facts from this other source apparently having the same meaning are coming to light in astonishing numbers. Charles Darwin foreshadowed the new era of investigation by his book "The Expression of the Emotions in Man and Animals." But the most positively scientific gate-opening into this great realm was made nearly simultaneously by the American psychologist, William James, and the Danish physiologist, Carl Lange. The combined results of these initial labors was what is known as the James-Lange theory of the emotions.

The main facts invoked by this theory are too obvious to escape any one: All emotional stages as of joy, grief, fear, anger, jealousy, love, are associated with more or less characteristic bodily manifestation, these often seeming to involve the entire physical framework. The theory says the bodily states thus manifested actually constitute the emotions. It is not, as the older theories had it, that the body is played upon, as it were, by some independent entity,

as a spirit, something as a piano is played upon by a pianist, but that the living organism's mode of responding to certain influences from the external world are the emotions.

With some modification later research has strengthened and extended this theory. All our sentiments, emotions, passions, the noblest and the basest alike, are the working together in response to stimulation of sense organs, nerves, muscles, blood vessels, viscera, glands. Finally, only yesterday and to-day come the discoveries of internal secretions and vitamins which are essentially special agencies for exciting the various body parts to their appropriate actions. Consequently, so much to the front have the activities of animal organisms been brought by the new discoveries and theories that reflex actions, tropisms, instincts, appetites, emotions, passions, have become the central interests of the day not only in the science of mind but in art, in literature and in nearly all practical life.

And through these activities, subject as they surely are to the laws of physiology and heredity, man's identification with the whole of living nature is made direct and inevitable. There is not an item in the list of structures and activities mentioned that is not common to men and some, if not the whole, of the animal world.

If all this does not mean filiation by descent with animate nature generally, what does it mean? We have reached a point in the study of man where it becomes clear that whatever theory of his origin shall finally prevail must be accordant with the major facts of his daily life. And any one who would contend that these facts do not necessitate belief in some form of evolution or natural transformation is compelled by the fact that he himself possesses the power of reason to produce a rational theory of his origin that accords better with the facts of his own nature and the nature of all living beings than does any transformational theory.

PROOF OF MAN'S CULTURAL EVOLUTION

By Dr. GEORGE GRANT MacCURDY

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The evolution of human culture is well exemplified by a study of the artifacts of the Old Stone Age in Europe. This age covered a period of several hundred thousand years. It is commonly divided into two periods—the Eolithic and the Paleolithic; the latter is subdivided into Lower, Middle and Upper Paleolithic. Cultural evolution has its parallel in organic evolution and, like the latter, its pathway is strewn with extinct forms. Of the two, cultural evo-

lution is subject to more rapid changes, its chief basis being human inventiveness. One invention leads to others by a system of budding and branching; so that a single invention may give rise to a whole cluster of related activities forming what might be called a culture-complex unit. The oldest clusters of human activities of which we have definite knowledge are the lithic and fire complexes; the lithic complex was superseded in part and supplemented by the use of such organic materials as bone, ivory and reindeer horn, which characterized the game-animal complex.

In a comparative study of the industrial remains of these various periods, there are certain broad distinctions to be drawn. Eolithic industry consisted largely of improvisations—of primary tools or implements such as the hammer-stone and the flint chip with utilizable edge or point. Secondary tools were few and simple, consisting largely of artificial chips; during the Lower Paleolithic period, the number of secondary tools was increased by the addition of the cleaver, a pointed implement chipped on both faces. A primary tool is one ready to hand—furnished by nature; a secondary tool is one which requires the use of a tool in its manufacture; tertiary tools are those which in their shaping require the use of primary and secondary tools and whose ultimate purpose is not the shaping of implements.

The Neandertalians of the Middle Paleolithic Period made no great advances over their predecessors. They possessed an improved technique, which is seen in the character of their nuclei and well-formed scrapers and points with carefully retouched margins; but so far as can be ascertained they did not go beyond the making of secondary tools—that is to say, their secondary tools served directly an ultimate purpose, were not used for the manufacture of tertiary tools. The technical processes from Pliocene times to the close of the Middle Paleolithic Period (well along toward the close of the Pleistocene) remained relatively simple.

It was reserved for the Upper Paleolithic Cro-Magnon races to inaugurate a new era. This was made possible through improvement in the preparation of nuclei from which long slender blades could be struck. The next step was important additions to their stock of secondary tools (various forms of the graver, microliths, small knives and awls) which enabled them to make extended use of bone, ivory and reindeer horn, leading to two capital results—the invention of a set of tertiary tools and the dawn of the fine arts.

Upper Paleolithic or Cro-Magnon culture was very early transformed through the addition of the secondary shaping tools produced from bladelike flint flakes, without which it would not have been possible to make an array of tertiary tools such as the bone needle, the javelin point of bone, ivory or reindeer horn, the javelin

shaft, the dart or javelin thrower and the harpoon of reindeer horn; nor would the Cro-Magnons have been able to embellish their dart throwers and satisfy a rapidly developing artistic sense by producing various objects of art and of personal adornment.

CONTEMPORARY EVOLUTION OF SOUTH SEA ISLAND SNAILS

By Dr. HENRY E. CRAMPTON

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To the majority of people evolution means a long line of successive generations, and the production of a new kind of living thing differing from its earlier ancestors to such an extent that it can justly be called a new species. This is evolution, it is true, but the special student knows that the larger differences which come about in long time are the accumulated smaller variations such as all creatures display when they are compared with their immediate parents. No one has yet found a single animal or plant that is exactly like either of its progenitors or like another of its own family. Hence every one knows that "individual differences" come about naturally. When such differences are summed up in time to be more obvious contrasts, we speak of "varieties," or "sub-species"; and when two kinds of descendants from common ancestry come to be even more separate they are called species.

During nineteen years, the present writer has been investigating the processes of change displayed by some of the land-snails that live in the forests and jungles of many islands of the South Seas. At first sight, the animals do not seem interesting, but nevertheless their study has revealed abundant evidences that new "kinds" have actually come into existence within that short period of time. Some of these "kinds" are only slightly different from their parent stock, but others are more distinct, and, as real varieties, they are well on their way to the status of new species.

The evidences in question have been secured through a fortunate combination of circumstances. An American naturalist named Garrett worked among the islands of the great Pacific Ocean during many decades of the nineteenth century, and he left full descriptions of the species of snails belonging to a genus called Partula, as they were distributed in his time. He showed how each group of islands possesses its own species not found elsewhere, and how each island of a single group is the home of unique kinds which are closely related to the species of nearby places but which have come to be distinct in correlation with the separation of the islands where

they occur. Furthermore, the different valleys of an individual island, like Tahiti, bear distinct varieties of one and the same species, which are even more nearly related to one another, as their differences are relatively slight in degree.

My own work consisted in going over much of the ground covered by Garrett, collecting all the species and varieties in the various valleys and islands, and comparing them as they now exist with what Garrett observed and described. Many a colony proves to be a much changed assemblage when contrasted with what it was a few decades ago.

Perhaps the most striking evidences were found in Moorea, an island near Tahiti in the Southern Seas. Eighteen years ago, new "kinds" were found which were apparently not known to Garrett, and which could not have been present in his time in the valleys where they first came to light. It is still more important that the writer has found during the last three years new kinds of very distinct nature which had not been present in the same areas sixteen years previously. Many of these are what the biologist calls "mutations," or offspring that differ from their immediate forebears in very obvious respects and degrees. For example, a few rare specimens possess shells that twist in a spiral that is the exact opposite of what the parent had. Others are "dwarfs," while still others display patterns of color that are unique.

Thus we have in nature the elementary episodes of real bodily change that need only to be added up during successive generations to result in the production of varieties and even species of new character. It does not require very much in the way of reasoning to recognize that such elementary episodes are just as truly evolution as the longer process of organic change which is accomplished merely by the summing up or accumulation of the small diversities that come about with every new generation.

MAN'S EMBRYONIC TAIL

By Dr. ADOLPH H. SCHULTZ

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How can a self-respecting scientist claim that his and everybody else's ancestors once possessed tails like those of monkeys? For no less a reason than that every man at an early stage in his own life-time is ornamented with such an appendage, which, to be true, serves no other purpose than that perhaps of making him feel justly proud of the fact that this organ long ago ceased to be a permanent part of his outer body.

The embryologist has irrefutable and abundant proof to demonstrate that man, long before birth and when measuring but a third of an inch, bears a true external tail one sixth the length of his body. This tail projects for a considerable distance beyond the place where the legs branch from the trunk. It contains anywhere from 7 to 9 vertebral rudiments, bringing the total number of segments in the spinal column to as many as 38. This tail soon becomes completely overgrown by neighboring parts and disappears from the surface. Some of the vertebral rudiments become resorbed so that in adult man there are only 4 or 5 of them left—small vestigial bones of the so-called coccyx at the lower end of the spine which in adult man consists of only 33 or 34 vertebrae. Even the last of these lies in full-grown man, when sitting on a chair, very considerably above the seat. This goes to show that the embryonic tail of man, particularly the bony elements in it, shifts in an upward direction in the course of growth. The spinal cord projects at first beyond the thirty-eighth vertebra, that is to say to the outermost tip of the tail; with the advance in age this vital part of his nervous system also migrates upward, and even more so than does the spinal column, since in the adult the cord reaches only as far as the twenty-first vertebra.

Embryology furnishes still further justification for comparing the vertebral rudiments in the tail of unborn man with the tail vertebrae in monkeys. In many of the latter are found on the lower side of the first few caudal vertebrae typical so-called chevron bones, which protect the blood vessels supplying the well-functioning tail. In an exactly corresponding place in the human embryo occur rudimentary structures which can unmistakably be identified as nothing else but these chevron bones.

The undoubted tail vertebrae, amounting in total length to about 16 per cent. of the sitting height in the embryo, have shrunk in adult man to less than 4 per cent. of the latter measurement. Even in adult life these last segments of the spine are readily diagnosed by the muscles, which are attached to them, as true tail vertebrae. In some individuals a greater variety of these muscles is found than in others; they are always of a rudimentary character, but they invariably correspond to muscles found in the tails of monkeys. Whereas in man they are no longer capable of wagging the tail, which has become internal, their purposeless existence can alone be explained as last vestiges of formerly well-functioning muscles.

The regular, normal occurrence of a proportionately large outer tail at an early and temporary stage in the development of man, together with the unequivocal remnants of true tail vertebrae and muscles, in the full-grown person, forms overwhelming evidence for

the only logical assumption that man, as well as monkey, descended from ancestors with well-developed tails. Only from such progenitors—no matter how remote—can man have acquired these absolutely useless but significant structures, and, indeed, this reminds one of the passage in the Bible: "The sins of the fathers shall be visited upon the children!"

In some apes, notably the orang-outang, the evolutionary reduction of the tail has gone further than in man, since in the former only three, sometimes two, tail vertebrae have remained and the adjoining muscles are still more rudimentary than in man's own anatomy. Moreover, a human being is born occasionally with an outer tail. Such a case, for instance, occurred some few years ago in Baltimore, and a reputable scientific journal gives an account of a twelve-year-old boy who had an outer tail of the record length of nine inches. These so-called soft tails contain no vertebrae, but blood vessels, muscles and nerves, and are of the same consistency as the short tail of the Barbary ape.

The embryologist in searching for truth in his field can not escape noting the striking resemblances between man, ape and monkey in early development which can be understood only by assuming one common origin for all, from which they inherited the tendency for the same growth processes. These processes have become modified in certain forms through a variety of later specializations. A long chain of proof has been produced by science for the further conclusion that the human body in a number of points is less removed from ancestral conditions, and hence remained in some parts more original and primitive than have some of man's simian cousins.

EVOLUTION AS AN ALLY OF RELIGION

By Dr. WILLIAM PATTEN

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It is obvious that the outstanding teachings of evolution are the same as the familiar teachings of religion. For the universal reign of law and order, which it has been the special privilege of science to reveal, is nothing more or less than the revelation that nature is a unified cooperative system, and that those better results, called evolution, are only achieved through better mutual service by all its constituent parts, and by their better submission, or adaptation to one another's requirements. That is the essence of the moral and ethical teachings of Christianity, as it is the essence of the moral and ethical teachings of evolution.

And the law of "natural selection," which is the essence of the much maligned "Darwinism," is in reality the expression of a discriminating, selective action in nature, in effect identical with the discriminating disciplinary laws of religion.

This disciplinary natural law merely means that whatever is fitting, or right, or true, whether it is physical, or organic, or vital, or spiritual in its nature, shall prevail, and shall yield its appropriate fruits. If it is not fitting, or if it is not right, or not true, it shall be fruitless, and shall not prevail.

In other words, truth has a saving power and a creative compulsion of its own. We call it the compulsion of intelligence. That is *why* man is compelled to seek the truth and to use it for his own salvation and betterment. And the *doing of that* is what we call science. But if we do not use the truth when it is discovered, if the truth when it is discovered does not make us work and direct our work, if it is not reverified in terms of human conduct, science will be sterile; it will neither bear its appropriate fruit nor have the vitality of reality.

Thus this compelling pragmatic law, which Darwin so clearly saw in operation in plant and animal life, and which he called "natural selection," is the same law that is so clearly expressed in Biblical teachings, as for example:

> And even now the axe is laid unto the roots of the trees: therefore every tree which bringeth not forth good fruit is hewn down and cast into the fire. But the root of the righteous shall not be moved.

And so, if we attempt to summarize the creative methods of evolution and to estimate their directive influence on ourselves, physically and mentally, it is not surprising that the narrower terminology of science inevitably changes into the broader moral and ethical terminology of idealism, or religion, or into that of any real creative process, such as art, business or politics.

This means that in the last analysis religion is merely a different name for science; the one being chiefly concerned with the immeasurable oneness, or godliness of nature-action, the other with its measurable manyness, or its distinguishable parts. But both seek to discover, to interpret and to utilize the same realities; and when that is rightly done they will be in ethical agreement; that is, they will dictate to mankind essentially the same conduct and justify essentially the same faith.

Thus science and religion offer the same incentives to action and have the same purposes to accomplish; and science expresses in her more comprehensive formulas precisely what all the great religions of the past and present have tried to express in their teachings, but without that sure and intimate knowledge of nature-action which

science gives us, and which is so essential to the truthfulness and sanity of any kind of religion.

I repeat, there is no difference between what is vital in science and what is vital in religion. In fact, underneath, science *is* religion, and religion *is* science. The differences which cause so much confusion are in their protective coverings of dogmas, ceremonials and procedures. They are differences between people; between those with more or less scientific qualities of mind and those who have little or no such qualities.

And so, it seems to me that the study of evolution, *as a whole*, more than anything else, will help to minimize the antagonism between religiously minded and scientifically minded people, and will help them to work more peacefully and happily together. For young and old, for high-brow and low-brow, the study of evolution makes life more significant and more beautiful. It justifies their faith and fortifies their ideals. It makes God a more imminent reality. It helps all of us to understand the purpose of life and how to accomplish it.

That is why I teach evolution.

BLOOD REACTIONS OF MAN AND ANIMALS

By Dr. MICHAEL F. GUYER

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SINCE Darwin's day important new evidence of evolution has been discovered, based on certain blood tests which give a scale of relationships among various groups of animals. Some years ago Reichert and Brown showed that in different kinds of structurally related animals the corresponding proteins and other vital substances of the different species exhibit chemically the same degree of relationship as that indicated by their position in the zoological scheme of classification. Thus, when the red coloring matter of the blood is reduced to crystalline form in blood from different kinds of backboned animals, although each species has its own individual type of crystal, the crystals of all species belonging to the same genus fall within the same crystallographic system, and generally within the same group in that system. Reichert, furthermore, has shown chemical relationships of the same general nature in the starches and tissues of parent plants to those of the hybrids between such plants. In other words, the more nearly related in classification different kinds of plants or animals are, the more nearly identical they are in their underlying chemical constitution. Such a condition is exactly what would be expected if the forms in question have evolved from a common ancestry.

But an even more convincing demonstration of evolutionary relationships is to be found in the reactions of the blood-serum of animals under certain conditions. When into the bloodstream of a given animal, for example, protein from an animal of different species or from a plant is injected, the animal so treated will have antagonistic or neutralizing substances of various kinds termed antibodies developed in its blood. Thus poisons called toxins, derived from bacteria, produce anti-toxins. Invading bacteria also lead to the production of sticky substances which clump bacteria of the kind used in their production if the two are brought together in the blood-serum of the animal into which the bacteria were originally introduced. Likewise a tissue or even the blood-serum of one kind of animal injected into the circulation of another animal of different species brings about the formation of a class of antibodies known as precipitins. These form a precipitate when the blood-serum of the treated animal and an extract of the special tissue used are brought together in a test tube. All such immunological reactions show considerable degree of specificity; the antibody will react fully only with the particular kind of protein used in its production.

In a remarkable series of studies in which he examined the blood from 900 different animals, Nuttall demonstrated some twenty years ago that by the precipitin test a scale of actual blood relationships among animals can be established. Recent refinements of the method together with the employment of other types of blood reaction all tend to confirm his conclusions. If, for example, a rabbit has been repeatedly injected with human blood, its blood-serum when mixed with slightly diluted human blood-serum in a test-tube will almost instantly yield a noticeable precipitate, although a control mixture of human blood-serum and the blood-serum of an untreated rabbit will remain clear. Closeness of relationship is determined by finding the dilution in which the serum tested will react. For instance, Nuttall found that when rabbit-serum which earlier had been treated with human blood-serum is mixed with moderately diluted blood-serum of man, apes and monkeys, respectively, it reacts to all, though in varying degree. When mixed with more highly diluted sera from such animals it forms a precipitate only with the serum of man and the manlike apes (chimpanzee, orang-outang, gorilla), the chimpanzee standing nearest to man.

Thus the chemical and other physiological processes of living organisms no less than their anatomical structures or geological history point to a relationship of various species which is intelligible only upon the influence that such species have sprung from a common ancestry.

THE RELATIONSHIP OF MAN AND ANIMALS

By Dr. R. S. WOODWORTH

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WHILE much of the evidence on the evolution question is technical and complicated, there is one broad view of the matter that is plain and simple, and it is this broad, simple view that really makes evolution so appealing an idea to all students of plant and animal life.

As you drive along a country road, you come across a poultry farm where all the chickens are pure white. A little farther along, you see another with all red chickens. You ask how it happens that one farmer has all white chickens, and the other all red; and the answer is that one is incubating eggs from one breed of hens, and the other from another breed. The pure white hens have a common ancestry and are all blood relations. So of the reds, and of any pure breed. If the whites are related to the reds, the relationship is not so close, and you would have to go further back in the pedigree to find the common ancestor. But as we know that various special breeds have sprung from the same general stock of hens, we have good reason to believe that all hens are blood relations. Those of the same breed are closer cousins, those of different breeds more distant cousins; but all hens are cousins.

We can say the same of dogs or pigeons. We know, as a matter of breeding history, where and when the more recent breeds of these domestic animals originated; and we know that those of the same breed are descended from the same ancestors, and are comparatively close cousins, while those of different breeds are more distant cousins.

Now suppose we ask in an open-minded spirit whether pigeons are closer cousins to hens or to dogs. The answer can not be in doubt, once we allow the question to be put. Pigeons and hens have the marks of a common descent. It is quite easy to conceive of two similar species as being related species, once we carry over our knowledge of breeds to the larger and more distinct groups which we call species. Take the "cat family," including lions, tigers, bobcats, house cats and others. The more we know of their internal anatomy and of their behavior, the easier it becomes to believe them a real family, in the sense of being all blood relations. Extending this idea still further, we readily come to believe that all mammals are a family, and all birds another family.

We need, of course, to be on our guard against merely superficial resemblances between different sorts of animals. Penguins

and seals have considerable resemblance. The penguin doesn't fly any more than the seal runs on four feet; but they both swim and dive most expertly, and in a very similar manner. The penguin has flippers in place of wings, and the seal has them in place of legs. For all that, when carefully studied, the penguin is certainly a bird, and the seal a mammal. That means that the seal and penguin are by no means close relations. The seal is closer to the cat, by descent, and the penguin is closer to the hen. It certainly seems a sensible view, once you get the hang of it.

But if we have reached the point where we think of mammals as one immense, but genuine family, and of birds as another similar family, does common sense force us to stop there? Rather, when we come to know the fundamental resemblances between birds and mammals—in their bones, their muscles, their hearts, their brains—we are much inclined to believe in a fairly close relationship between birds and mammals, and indeed between all vertebrates, as contrasted with insects, molluscs or jellyfish. The whole animal kingdom seems made up of several great families, and probably even these are interrelated, if we could trace the ancestry back far enough. As regards plants, the whole idea could be developed there just as easily as in the case of animals.

One big doubt, however, arises. If all mammals, for example, are a true family of cousins, then should we not expect to find all gradations? Should we not be able with a complete collection of animals at our disposal from all parts of the world to arrange a zoo as a long row of cages, passing from the camel to the lion, for example, by small differences without a break anywhere in the series? As a matter of fact, a collection of living animals could not be arranged without leaving many large gaps. But then, ancestral breeds may have died out, leaving derived breeds in possession of the earth. This is not only a natural supposition, but is a fact, revealed by the fossil remains of the animals of old. The animals of former geological ages were not the animals of to-day. The horse as we know him did not exist, though horse-like breeds, that may well have been the ancestors of our horses, were then alive.

In considering the family tree of animals, we have to remember that the live species of to-day are the leaves on the outer twigs. We have before us, alive, only the outer shell of the tree. We can not see into the interior of the mass of branches; we can not see, directly, the past condition of the tree. We can partially reconstruct the past of the tree by laboriously digging up the remains of past seasons now lying buried beneath the tree, and piec-

ing them together as well as may be. In spite of the motley array of leaves which we now see on the outside of our family tree, we find, beneath the tree, good evidence that the tree was formerly more uniform than now, that many branches have died, leaving the rest to fill the space, and that all the branches have arisen from the same parent stem.

But does man fit into this scheme of things, and if so where? Well, there is no manner of doubt that man is a mammal. The more you know about his bones, muscles, blood, nervous system, the clearer it becomes that he belongs in the scheme. Nor is there any doubt as to his nearest living cousins; they are certainly the higher primates, the apes. Man is not descended from the chimpanzee, any more than the chimpanzee is descended from man, but they are leaves on the same branch of the family tree.

Fitting man into a place in the general family tree of animals is not humiliating, nor dangerous to morals. It does not lower man in the least; it leaves him just the same as before, with all his distinctive and remarkable qualities. A great artist may have very commonplace cousins, but he is a great artist just the same. Man's duties and opportunities correspond to his abilities and are not abated one whit by the fact of his having cousins less highly endowed. All that sort of objection to evolution is not commonsense, to say the least. If the brotherhood of all men is a humane conception, the cousinhood of man and animals is no less so. Once we see that man has an organic place in nature, we have a sense of being at home in the natural world that is a great satisfaction and, I believe, a great spiritual gain.

But, it may finally be asked, what does the Bible teach regarding evolution? It is fair to say that the Bible never raises the question, and consequently can not be expected to furnish anything like a direct answer. The answer, at the best, would have to be read into some passages by implication and would always be open to various interpretations. If anything is clear in reading the Bible, it is that we have here a religious book, a book concerned with man's religious life, and not with natural science. It is not a treatise on biology any more than a treatise on astronomy or chemistry or arithmetic. It leaves these fields entirely aside. How unfair to the Bible, then, how prejudicial to its continued influence, to lug it in and attempt to extort an answer from it on matters which it does not discuss and which lie outside of its chosen field!

FUNDAMENTAL FACTS IN THE HISTORY OF MATHEMATICS

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THE student of the general history of science can evidently not hope to become familiar with all the details relating to the history of the various subjects. Fortunately, some historical facts are very rich in implications, and the mastery of a few such facts constitutes an almost inexhaustible source from which the thoughtful student is able to deduce, with a fair degree of accuracy, a vast amount of well-coordinated historical information. In the history of mathematics such deductions are unusually safe in view of the fact that mathematics is based on a comparatively small number of postulates, and hence the mathematical routes, from the simpler to the more complex results, have, as a rule, not varied much, especially as regards the part of these routes within the domain of elementary mathematics.

There are few mathematical facts which are richer in historical implications than the so-called *Heron formula* for the area of a plane triangle. Millions of young students of mathematics have been pleasantly surprised by the fact that this area is exactly equal to the square root of the product obtained by multiplying together half of the sum of the sides and the three remainders obtained by subtracting from this half sum each of the sides separately. The great usefulness of this rule in land surveying is at once evident, and the difficulties involved in its proof are sufficiently serious to reflect great credit on the Greek mathematician who first proved it. One might at first be inclined to think that the ancient Greeks would have welcomed this proof with great enthusiasm and would have lavishly praised its author on many occasions, since this author reflected eternal glory on the Greek race. On the contrary, we find no evidence of such praise in the extant Greek literature. This literature does not even furnish any evidence as to who this author was. An Arabian writer of the tenth century stated that it was Archimedes, the greatest mathematician of antiquity, and modern mathematical historians are inclined to believe that this is correct. The scantiness of historical data relating to this fundamental rule is in itself rich in historical implications. The rule relates largely to practical applications of mathematics, and it is well known that the early Greek mathema-

ticians paid little attention to such applications. They studied mathematics with a view to securing intellectual penetration, and not with a view to finding results which are useful to the so-called practical people. That is, they studied *pure* mathematics rather than *applied* mathematics. It is true that we find some deviations from this general rule, especially in the works of Heron and some of the later Greek writers, but it is a fundamental historical fact that the people who made the greatest early advances in the development of mathematics took little interest in its applications.

While the scantiness of historical data relating to the fundamental rule under consideration is rich in historical implications, the fact that the rule was definitely proved at such an early date is still richer in such implications. The modern student of mathematics usually proves this rule for the first time in his first course in trigonometry. As the student of mathematics usually rediscovers a large number of results which were known before his day it is likely that this rule was rediscovered a large number of times, but we have no evidence that this was the case in ancient times. A more general but not quite accurate rule was used in India by Brahmagupta in the seventh century, and a new proof of the rule under consideration appears in an Arabian work written in 1036. The Roman surveyors also used this rule, but it is likely that all these peoples obtained it from the works of Heron, which were used widely either in the original or in a translated form.

We have here a definite fundamental rule relating to elementary geometry, which we now commonly express by the formula

$$\sqrt{s(s-a)(s-b)(s-c)}$$

where a, b, c represent the sides of a plane triangle and s represents half of their sum. Two interesting historical facts relating to this formula are that the ancient Greeks proved it but did not esteem it very highly and that it is of such an advanced character that notwithstanding its great usefulness the modern student of mathematics usually does not prove it before his freshman year in college. These two historical facts throw much light on the Greek attitude towards mathematics as well as on their advancement, for they could evidently not have proved such a formula without knowing a large number of more elementary theorems relating to elementary arithmetic and elementary geometry. The former of these facts also raises the question whether our modern emphasis on applications is most conducive to progress in science.

It is difficult to estimate the value of the wholesome influence of Heron's formula. It embodies an intellectual penetration of high order which doubtless has been a source of inspiration to many thousands of students. The facts that it is accurate and can be

easily employed, if the operation of extracting the approximate square root of a positive number is known, are significant. The former fact naturally appeals especially to the seeker of absolute truths, while the latter throws light on the meagerness of the mathematical insight of those who knew a rule which is equivalent to this formula but replaced it by inaccurate ones which require only rational operations. As an instance of this we may mention the remarkable fact that the Roman surveyors used also such an inaccurate formula as

$$\frac{a(a+1)}{2}$$

for the determination of the area of an equilateral triangle whose side is a. Mathematics practically from its beginning to the present time has been concerned both with accurate methods and with methods of approximation. In many cases it is impossible to determine whether the ancients who used the latter were aware of the fact that they led to results which are only approximately true. When this can be determined it throws much light on the mathematical insight of the people concerned.

A fundamental fact relating to the history of mathematics is that a large part of this history is necessarily based on secondary sources of information. This is especially true as regards the history of Greek mathematics. We do not even have the original of Euclid's "Elements," but the modern accepted texts of Euclid are based on various transcriptions. A rule equivalent to the formula considered above appears in various of the extant works of Heron, but all these are probably transcripts, and the proof may possibly be an interpolation. Hence the statement that the ancient Greeks knew and proved this rule must be regarded as one based upon secondary evidence, which is now commonly accepted by the specialists dealing with the history of Greek mathematics. This evidence is, however, less satisfactory than that furnished by the discovery of original works. In the case of Egyptian mathematics the work of Ahmes, written about 1700 B. C., furnishes evidence of the latter type. For more than three thousand years this work had ceased to influence mankind when in 1877 A. Eisenlohr awakened it by a translation into a modern language. It could then no longer instruct the world in mathematics, but it could and did furnish the world very definite information in regard to mathematical developments at the time when it was written.

One of the most surprising facts in the history of mathematics is the slowness with which negative numbers were generally adopted. Even the eighteenth century suffered from a lack of a satisfactory introduction of negative numbers, according to J. Tropfke, "Ge-

schichte der Elementar-Mathematik," volume 2 (1921), page 78. The modern student of elementary mathematics uses negative numbers extensively in his work in algebra, trigonometry and analytic geometry. Hence the fact that no satisfactory theory of negative numbers became generally known before the first half of the nineteenth century throws much light on the status of these subjects before this time. Even the founder of analytic geometry, R. Descartes (1596–1650), thought that negative numbers would increase as their absolute values increase and hence he must have had a very imperfect conception of the modern use of coordinates in analytic geometry.

The imperfect understanding of negative numbers by eminent mathematicians of comparatively recent times may be illustrated by the fact that the noted English mathematician J. Wallis (1616–1703), regarded them as greater than infinity in view of the assumption that by diminishing the denominator of a fraction with a constant positive numerator we continually increase the fraction even when the denominator becomes negative, as follows:

$$\frac{1}{4} < \frac{1}{3} < \frac{1}{2} < \frac{1}{1} < \frac{1}{0} < \frac{1}{-1}$$

At another place, however, J. Wallis stated correctly that positive and negative numbers are opposite just as profit and loss. The great Swiss mathematician, L. Euler (1707–1783), first noted that the positive and negative numbers are connected both at 0 and also at ∞. Contrary to what is sometimes stated this does not harmonize the earlier views that negative numbers are both greater than infinity and also less than zero, for the connection at infinity is not a continuous one.

Although no satisfactory theory of negative numbers became generally known before the first half of the nineteenth century it should not be inferred that we find no evidence of the successful earlier use of these numbers. The Indian mathematician, Brahmagupta, born in 598, placed a dot above a number to indicate that it is negative and another Indian mathematician, Bhaskara, born in 1114, used names for positive and negative numbers which correspond to our words of credit and debit. Indian mathematicians recognized also positive and negative square roots, but noted that "people do not approve a negative absolute number." In Europe negative numbers were used occasionally long before the legitimacy of this use was fully established, but some mathematicians were very conservative along this line. In particular the noted French mathematician, F. Vieta (1540–1603), did not admit negative solutions of equations. Even in the eighteenth century

some critical mathematicians like Robert Simson, of Glasgow, did not admit the legitimacy of operations with negative numbers.[1]

The history of mathematics concerns itself not only with the first use of certain fundamental concepts but also with the question when this concept came into general use. This question is frequently very difficult since later mathematicians did not always adopt promptly what was best in the work of their predecessors. In fact, the merits of certain mathematical work was frequently not fully appreciated until its influence on later developments became manifest. In the case of negative and imaginary numbers, for instance, it is not likely that those who first used them had a clear idea of the fundamental rôle which they were to play in the later developments of our subject. Mathematical historians seem now to agree on attributing the first satisfactory geometric theory of complex numbers to the Norwegian surveyor, Caspar Wessel (1745–1818), who published a memoir on these numbers in 1799. This theory did, however, not become generally known until much later, and various later writers may have developed it independently. In 1833 the Irish mathematician, W. R. Hamilton (1805–1865), presented before the Irish Academy the first satisfactory arithmetic theory of these numbers.

The fact that satisfactory theories of complex numbers did not become widely known before the latter part of the first half of the nineteenth century throws much light on the limitations of the mathematical developments which preceded this period. Hence such fertile facts should be grasped first by the student of the history of our subject. Similarly, the fact that no satisfactory theory of the solution of a general system of linear equations was possible before the latter half of the nineteenth century since the theory relating to the rank of a determinant was not developed earlier also throws light on the treatment of this subject in the earlier works. The fact that the French mathematician, A. L. Cauchy (1789–1857), is often called the founder of determinants implies that the earlier developments relating to this subject were relatively meager. In fact, in our freshman courses in algebra we often teach theorems relating to determinants which were unknown at the beginning of the nineteenth century. In particular, the rule known by the name of Sarrus for expanding a determinant of the third order by repeating two lines of the determinant was first published in 1846.

In view of the fact that in geometry many simplifications result from the use of the point at infinity it is interesting to note that in

[1] M. Cantor, "Vorlesungen über Geschichte der Mathematik," vol. 4 (1908), p. 80.

1609 J. Kepler (1571–1630) said for the first time as far as known that parallel lines meet at infinity, and that somewhat later G. Desargues (1593–1662) established the use of the point at infinity in geometrical work. The term *convergent* as relating to an infinite series appears also for the first time in the seventeenth century, *viz.*, in a work by the Scotch mathematician, James Gregory (1638–1675). Not only does the term convergent series appear in this work, entitled *Vera circuli et hyperpolae quadratura,* 1667, but the modern notion of the nature of such a series appears here more clearly than in any earlier work. The great importance of this notion in elementary calculus and elsewhere seems to justify the fact that we include its naming among the fundamental elements of the history of mathematics.

We shall also include among these elements the first use of imaginary exponents by L. Euler in 1740, when he communicated to John Bernoulli I the very interesting formula

$$2 \cos x = e^{ix} + e^{-ix}$$

where $i = \sqrt{-1}$. This implies that all the earlier mathematicians confined their attention to real exponents. In particular, I. Newton could not have developed the binomial theorem for imaginary exponents and hence the common statement that he proved this theorem for the general exponent can not be accurate. What is more important to the mathematical historian is the fact that such an interesting formula naturally raised many questions as regards the use of imaginary exponents, and one finds in this fact an incentive to mathematical progress in the latter half of the eighteenth century. In particular, the need of a better understanding of imaginary numbers became more and more apparent, and this need inspired much of the mathematical progress during the latter half of the nineteenth century.

From what precedes it is clear that mathematics was not developed in the exact order in which we now present it to the student. Some of the things which we now commonly teach to the freshman in college were unknown at the beginning of the nineteenth century. On the other hand, even the ancient Greeks carried some of their mathematical developments beyond the point reached now by college students. A fundamental fact of the history of mathematics is that it is impossible in a general history of this subject to present a clear view of all the known developments. A general history must perforce make selections, and the most important principle in making these selections seems to be to exhibit first the most fruitful concepts. For instance, from the fact that negative and imaginary numbers did not receive general recognition before the beginning of the nineteenth century it is clear that the solution of the general

quadratic equation was not commonly understood before this time; and from the fact that the ancient Greeks did not use negative numbers it results that they could not have solved this general equation even formally.

It is customary to begin a study of the history of mathematics by considering first the contributions due to those who either made the earliest known advances in this field or who transmitted such advances. From the standpoint of securing well-coordinated historical insight into the development of mathematics there are many advantages in beginning with modern times. For instance, the fact that our modern method of studying a system of *m* linear equations in *n* unknown was first developed in the latter half of the nineteenth century throws much light on the work in linear equations during all the earlier times, and the study of this work will then tend to exhibit forcibly the advantages of the modern method and the advantages of living in the modern mathematical world. In fact, one may be led by such methods to marvel at the fact that the great mathematicians of all preceding ages failed to discover these methods, and to appreciate more fully their attainments, notwithstanding their handicaps. Those who study the history of mathematics mainly for the purpose of getting a deeper mathematical insight will usually find it most advantageous to begin with the modern developments of the subjects whose history they are tracing, since these developments are naturally easier and more complete than the older ones, and the elements which are imperfect in the latter stand out more clearly when they are compared with the former.

The history of science may profitably be regarded as an exposition of the compound interest law as regards the development of fundamental concepts and hence it is very important to secure a clear notion with respect to the early development of such concepts. The nature of the compound interest law may be partly illustrated by the fact that if instead of giving fundamental concepts to the church Christ could have safely invested one cent at 4 per cent. compounded annually for the benefit of the church of our day the amount would now be equal to more than the value of a volume of gold weighing many times as much as our whole earth. The value of his fundamental concepts to the modern church can obviously not be measured in terms of gold or in terms of what gold would buy. Similarly the value of the fundamental concepts of science can not be translated into material standards alone, even if the equipment of the modern American university might tend to suggest the possibility of such a translation. A proper presentation of the history of science should do much to counteract this tendency, as well as to exhibit the enormous cumulative effect of the fundamental concepts.

ANTHROPOLOGY AND THE ENDOCRINE GLANDS

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ALTHOUGH the influence of the sex glands, or, more properly speaking, of the deprivation of the reproductive organs, upon the individual characteristics of animals and human beings had been known for centuries, and although numerous pioneer observations and speculations antedated it, it was not until Charles Edward Brown-Séquard read a famous paper before the Société de Biologie of Paris on June 1, 1889, on the effects upon himself of injections of sex gland extracts that the far-reaching possibilities of a chemical mechanics of personality determination became manifest. Three years before, Victor Horsley, in England, had published a paper on certain "Functional nervous disorders due to loss of thyroid gland and pituitary body," in which an influence of these two glands upon the metabolism and condition of the nervous system was suggested. But the positive statement of Brown-Séquard concerning the effects upon various bodily and mental functions, such as appetite, physical strength, mental energy and ability to concentrate, channeled the territory for an ever-widening river of research and investigation.

Yet, although Pierre Marie published his observations on the effects of the pituitary gland in the disease acromegaly upon the bodily proportions, and Murray two years later, in 1891, published clinical observations on the personality modifications of the administration of thyroid gland, no attempt has come to my notice of the construction of a fundamental chemical theory of individuality for the next twenty years. In 1912, a German, R. Stern, published a monograph entitled "The bodily characteristics of predisposition to tabes" in which, basing his conceptions upon a careful study of individuals suffering from the diseases of the nervous system, locomotor ataxia and general paralysis, which sometimes develop in syphilitics, in which he definitely voiced the conception of a "polyglandular formula" as determining differences in form and function between individuals, as well as differences in resistance to disease and possibilities of infection. He compared different individuals with those suffering from thyroid and pituitary gland affections of their personality and declared that glandular differences in normal individuals could be deduced from variations in their morphology observable even in childhood and during adolescence. He

also emphasized that the variable contributions of the different glands of internal secretion to the make-up conditioned not only form and function variations, but also the receptivity toward disease and the character of disease as it developed. In the same year the Italian Nicola Pende read a paper before the Congress of Internal Medicine in Rome in which he compared various types of habitus with types established by glandular dominance and used the term "individual endocrine formula." As in the case of so many of the cardinal ideas of the sciences, it was as if a solution was waiting for some particle of disturbance to permit a great crystallization. Many minds all over the world were affected by the great conception of an endocrine-chemical determination of the anatomic and functional properties of human beings.

Dr. Joseph Fraenkel, who practised neurology in New York, contended and lectured for years that racial as well as individual characteristics were greatly influenced by the inherent glandular equipment, but published nothing. It remained for Sir Arthur Keith, in a now classical paper entitled "On the differentiation of mankind into racial types," to stress the significance of the newly emerging endocrine conceptions for the ethnic problems of anthropology. He stated that he believed there was enough evidence at hand to attribute the significant differences between the Caucasian, the Mongolian and the Negro races, the differences which the anthropologist used in their classification, to differences in the degree of functioning of the thyroid, the pituitary, the adrenal and sex glands. Using structural differences, as the relation of the trunk to the limbs and *vice versa*, pigmentation, hair distribution and other characteristics, such as the mode of origin of the nose and the character of its development, and comparing these with the known and apparent effect upon the same characters in clinical disturbances of the glands of internal secretion, he constructed a valid case for his theory. In 1921 Bolk presented his view in which he extended the theory of Keith, adapting it to a conception of his own which explained man's origin and deviation from the ancestral primates as an effect of certain endocrine variations and dominations. Particularly he stressed the conception of an inhibition, by glandular action, of the early maturation of various structural and functional characteristics, as explaining certain curious resemblances of adult man to fetal primate.

But besides the influence of the glands of internal secretion upon habitus and physique and such individual and racial qualities as skin texture and coloring, hair quality and distribution, cranial and facial bone development, therefore including head form, which is a primary interest to the anthropologist, the large issues of intelligence and temperament, as well as individual and racial vigor and vitality, come within the endocrine domain, as also does the me-

chanics of the appearance of those abnormal variants who have influenced the course of culture and history.

One of the great achievements of modern science has been the release of thought from the theological dogma, even now accepted as gospel truth by hundreds of millions, that the personality consists of the manifestations of a "soul," a reality which is made of "spirit," opposed in its nature and activities to "matter," and consequently to the "body," palpably flesh and blood. In the past the scientific attitude had done good destructive work and paved the way for more rational conceptions. Not until quite recently, however, has it substituted any really satisfactory and useful data for those it demolished.

A number of thinkers of the seventeenth, eighteenth and nineteenth centuries evolved, partly out of their inner tough-minded consciousness and partly with the aid of the scanty knowledge at their disposal, mechanistic theories of human conduct. It was very bold of Thomas Hobbes in the seventeenth century to proclaim that the behavior of a man was simply the expression of his instincts. And the most daring of succeeding thinkers defied the gods in their heaven and the occupants of the seats of the mighty on earth when they declared that a man was just a machine. The substitution of the word "machine" for the word "soul" was a mental revolution. But it was an empty conception, because there was no concrete information at hand to supply the parts of the assemblage of the machine.

When Freud and his disciples appeared and showed that with the help of certain assumptions and terms a good many puzzling human reactions could be understood and riddles solved, there were those who shouted that a true mechanics of human nature was upon us. But it was not until the rapid accumulation of facts concerning the relation of the glands of internal secretion, producing substances which entered the blood and reached every part of the body with the blood, to the entire make-up of the individual and especially to the nervous system, before birth, and during development, adolescence and maturity, that we may be said to have attained real knowledge concerning the basis of important practical variations in individuality.

It is easy to observe that a man can be studied from the standpoint of his physical traits. That different people can be classified as types on the basis of their bodily characteristics is a truism. It is also familiar that a classification of individuals is possible on the basis of mental traits, for every one speaks freely about character and character types. Many minds have suspected that there must be some relation between the physical traits and the mental. Physiognomy and phrenology, and even palmistry, were built upon the foundations of that suspicion. But the genuinely scientific

phase of consideration of a possible connection was born when it appeared that chemical substances, the internal secretions, provided specific, concrete, observable and measurable links between the body and the mind.

When the remarkable changes in the skin, hair, teeth, bones, as well as the emotional and intellectual status of a cretinoid idiot, were produced by feeding thyroid, who but would not wonder at the inevitable suggestion that here at last was available the long-sought chain between the manifestations of temperament and habitus? And when it was found that all the other glands of internal secretion, the pituitary, the pineal, the parathyroids, the thymus, the adrenals, the gonads, had a profound influence as energizers, activators, coordinators, harmonizers and regulators of all the vital processes (as facts turning up daily in both the laboratory and the clinic amply proved), who but would not wonder whether it was not in them that the secrets of personality were hidden?

True, the rôle of integration of the various parts of the body had for long been ascribed to the nervous system alone. Yet the fact could not be blinked at that, apart from vague ideas concerning the size of the brain layers, and still vaguer speculations concerning possible peculiarities of construction, the conception could offer not even a good working hypothesis to explain and explore differences in personality.

On the other hand, the internal secretions are chemical substances. It had long been accepted in the inorganic world that differences between substances are due to differences in the chemistry of them. If they were mixtures of more or less similar substances, the differences between them were ascribable to differences in the relative amounts of the components of the mixture. When it was seen that great differences in the physical and mental make-up and reactions could result from a variation in the amount of an internal secretion acting in an organism, the analogy was complete. One could imagine that individuals, like all other combinations in the universe, were mixtures of similar substances; that individuals were different because of differences in the amount of the substances entering into their composition; and that the most important of these substances were the internal secretions, because they, fundamentally, controlled the production, distribution and consumption of energy as well as the way chemical reactions should go in the various cells, including the nervous system. Observation confirmed up to the hilt these conceptions. It had long been known that many disturbances and changes and even diseases of the personality occurred without any observable pathology of the nervous system. On the other hand, *careful examination showed that no disease or disturbance of any of the glands of internal secretion happened without some corresponding and often striking change in the per-*

sonality. Excessive or insufficient activity of a gland could determine the type of physique of an individual. Overaction of the thyroid or pituitary, insufficient action of the adrenals or the gonads, for example, could produce the taller types of individuals. Conversely, overaction of the adrenals or gonads, or insufficient action of the thyroid or pituitary could produce the shorter types. On the psychic side, similar relations were evident. The challenging enthusiasm of the man with the over-acting thyroid contrasted sharply with the phlegmatic apathy of the man with deficient thyroid function. The hypersensitive melancholy of the man with the failing adrenals emphasized the virile driving quality of the man with sufficient functioning of the same glands. The incorrigible optimism of the individual whose pituitary and gonads are providing more than enough of their secretions stresses the effeminate, passive, rather sad and weak textures of the stuff of him in whom they are relatively lacking or under-secreting.

The introduction of the metabolic viewpoint in anthropology will, I believe, lead to great and immeasurably important results. The conception of a metabolic determination of organismal construction and functioning must needs throw a great deal of light upon the problems of interaction of organism and environment, as well as the problems of organismal groups, varieties and races, and the problems of individual variation and differentiation of body and mind.

It has been definitely established among the invertebrates, like the fruit fly, that the chromosomal constituents, more or less independently of the environment (although even here the necessity of a standard environment, so-called, has been conceded), are the fundamental determiners of individual characteristics. Apparently this is because among the invertebrates the substances in the chromosomes constitute the fundamental machine. Among the vertebrates, however, another apparatus becomes evolved. This apparatus is the system of the endocrine glands. The significant fact should be stressed that it is only among the vertebrates that the glands of internal secretion begin to exert an important influence upon the local and general metabolisms. Among the invertebrates most of them do not exist or only their homologues have been demonstrated. Moreover, the glands themselves undergo an evolution as one ascends the vertebrate scale, an evolution which points to an increasing influence upon individuality. No parathyroid glands have been found in fishes. In amphioxus the thyroid is a saccular organ which opens into the pharynx, and is lined by a ciliated epithelium which secretes mucus. According to Vincent, nothing corresponding to the adrenals has so far been discovered in amphioxus. And there is a well-known difference between the effects of extirpations of the

sex organs in invertebrates and vertebrates. In invertebrates, as, for example, certain butterflies, extirpation of the reproductive organs either experimentally or by disease is not accompanied by any change in the organism as a whole. In other words, there are no metabolic repercussions of the loss. In vertebrates the general bodily and mental effects of such an experiment are well known.

This last example may indeed be taken to exemplify the complete principle involved. In the invertebrates the chromosomal substances alone determine the architecture of the individual. In the vertebrates their influence becomes indissolubly linked with the action of organs which they themselves create, but which have in turn a modifying effect upon them. In the vertebrates, in fact, it may be stated that the chromosomal substances determine the production of local tissues and local tissue tendencies. The endocrine substances act either to exaggerate and stimulate or depress and inhibit these local tissue tendencies. From this point of view the chromosomes may be said to be local or regional factors, the endocrines may be contrasted as the constitutional or distributive factors. Two general laws may be deduced from the existing mass of evidence—which for lack of space can not be detailed here—concerning the relations of the chromosomal or regional and the constitutional or endocrine factors.

(1) The internal secretions are chemical substances influencing (catalytically as stimulants or depressants, interpretable as accelerators or retarders) local tendencies in cells, tissues and organs dependent upon local chemical reactions and physico-chemical conditions.

(2) These influences and relations are specific, that is, the character or intensity of effect depends upon a particular specificity in the internal secretion and the chemical substances under consideration, neither of which can be completely replaced by any other substance.

Now viewing individuals as the outcome of the specific interactions of these two sets of factors, the important principle emerges for the anthropologist that whereas the chromosomal factors are more or less independent of the environment and possessed of, as it were, a tremendous dynamic inertia of their own, the endocrine glands are indeed the mediators between the organism and the environment. In the adaptations of the organism to the environment, both developmentally and in maturity, they play a most significant rôle. By their correlations they produce those remarkable examples of covariations which have aroused the curiosity and wonder of all naturalists interested in the mysteries of adaptation.

What is environment? It would be impossible to name every detail entering into the composition of an environment. But we may say that it is first of all food, the various chemical elements in

their combinations necessary for the grist-mill of metabolism, Na, K, Ca, Mg, I, Cl, S, Fe, P, C, N, O, H, and certain other of the elements in their simpler combinations as well as the more complex ones such as the pyrrol ring. Then there are heat and cold, variations in temperature which affect metabolism. Then there is light, the peculiar influence of the infra-red as well as the ultraviolet rays, the effect of which upon metabolism have recently become the subjects of intensive research. There are electrical and electromagnetic conditions of earth and atmosphere. There are the influences of altitude, gravity and sea-level, with their concomitant variations in atmospheric pressure. There are besides these physical and chemical factors, the psychic stimuli from living agents in the environment, friends, enemies, associates, sex and so on.

All these physical, chemical and psychic environmental factors act upon the glands of internal secretion, which are sensitive to them. Through their interaction, the function of a gland may be stimulated to the point of relative overactivity or depressed to the point of underactivity, within the physiological limits. Beyond these physiological limits lies pathology. But within them range a series of values which all come within the limits of the normal, but which are responsible for many of the differences perceivable in any group of so-called normals or between different normal groups.

The thyroid, for example, is most sensitive to the iodine content of the environment. When the iodine content falls below a certain minimum there develops goiter, accompanied generally by insufficiency, but sometimes by overactivity of the gland. That in turn influences the metabolism of every tissue in the body and especially the metabolism of the nervous system. A certain adaptive mobility of the metabolism, its ability to adapt itself to heat and cold changes, temperature variation, depends upon an adequate balanced function of the thyroid. The thyroid itself may be affected adversely by heat and cold, with retrograde effects upon the organism as a whole. Heat or cold acting for generations would be bound to leave its mark on the thyroid.

The parathyroid glands, which affect the sensitivity of the nervous system like the thyroid, but with a reversed effect—thyroid hyperfunction increases the sensitivity of the nervous system, while parathyroid subfunction also increases it—seem peculiarly sensitive to the calcium and phosphorus content of the environment. When there is an insufficiency of these, they hypertrophy. They regulate calcium and phosphorus metabolism in all the cells with profound influences morphologically and physiologically. They are probably also sensitive to light, particularly to certain regions in the ultraviolet portion of the spectrum which influence calcium and phosphorus metabolism. We know that the amounts of these ultra-

violet rays playing upon the earth vary during different seasons of the year, and in different localities. We may, therefore, legitimately ask: How much of local group and racial differences may be traced to parathyroid differences, depending in part upon variable calcium and phosphorus intake continued for generations and in part upon variable ultraviolet ray exposure during the same period?

As a matter of fact, one manifestation of such an influence was first discovered and described in 1921 by Krogh and the Jaensch brothers in Marburg, Germany. They have named the manifestation the eidetic phenomenon. The phenomenon consists of the following: There are certain children who have the capacity to recall at will, including every detail, which they can describe most vividly, scenes or pictures, maps or diagrams they have once viewed. This eidetic capacity is not the type of visual recall which is called visualizing and is sometimes spoken of as "seeing with the mind's eye." It consists in seeing, to the very last detail of design and color and at the distance at which it was originally viewed, all the spectacle once presented to the eye. It was found that feeding lime and cod-liver oil could cause complete loss of the capacity, to reappear when the lime and cod-liver oil is stopped. I have applied the methods of Krogh and Jaensch in the investigation of a number of children in several schools in New York and found a considerable percentage of such children. Those who had stigmata of the parathyroid deficiency—that is, those who were not capable of assimilating lime properly—responded to the feeding of lime and cod-liver oil by loss of their peculiar gift. They are by no means conscious of the possession of any unique or abnormal faculty, indeed believing that every one enjoys it. It is most frequent in children between the ages of five and seven, decreases in distribution as the children grow older, and is only rarely found in an adolescent.

The environmental factor to which the pituitary gland is sensitive, is, as Keith in particular has emphasized, the factor of mechanical stresses and strains. Occupation, therefore, but also other mechanically acting agencies, will affect parts of the body sensitized by the anterior pituitary hormone. In anterior pituitary hyperfunction, we see bony overgrowth at points subjected to the greatest mechanical stress. The posterior pituitary has to do with the metabolism of fats and carbohydrates. Groups of individuals who subsist for a long period of time on a diet consisting largely of starches or fats should be investigated from the standpoint of posterior pituitary functions. Body pigmentation is also connected with the pituitary gland function, and should be considered as well as the cortex of the adrenal glands in any research into the question of racial pigmentations.

Accumulating evidence has established that the adrenal cortex gland—or as some call it—the interrenal gland—is an antagonist, a sort of balancing wheel to the thyroid. Clinical considerations had long made possible the inference that while the thyroid accelerates metabolism, the adrenal cortex retards it. The recent work of Marine and his collaborators has confirmed this inference. All the environmental influences which affect the thyroid may therefore indirectly influence the adrenal cortex. As the latter is also involved in the mechanics of skin pigmentation, hair development and distribution as well as sexual differentiation, the possibilities become manifest of correlated variations because of adrenal—cortex—thyroid imbalance.

Both the adrenal medulla and the thymus glands are sensitive to the vitamin intake. The work of Riddle points to an implication of the thymus in lime metabolism. In spite of much experimental evidence, clinical considerations point to an importance of the thymus in growth and development and in response to the environment. Adrenalin, the secretion of the adrenal medulla, is of the greatest importance in what might be termed the excitement concentration of the environment. Its functioning is the now classical example of interaction of the endocrine system and the nervous system in adaptation to the environment. The sensitivity of the gonads to the physical and chemical agencies in the environment remains to be completely investigated. But the influence of long-continued use of aphrodisiac foods may be suspected. Variation in sexual differentiation and activity in different geographical groups will have to be studied from this viewpoint.

The great variability and sensitivity of the endocrine system introduces a new series of factors and a fresh angle of investigation in the long-mooted questions of the relations of the individual and the environment.

The nervous system is most sensitive to the psychic contents of the environment, the endocrine system to the physico-chemical contents. Both, however, interact to produce variations in individuality. Inspection of the results of such interaction, particularly the results of endocrine dysfunction, can not but drive home the far-reaching significance of endocrine relations to the environment and the nervous system in racial and group investigations. No one is more aware than the writer of the limitations of our knowledge of the endocrine glands. But it seems to him manifest that in the explanation of similarities and dissimilarities in racial and geographical groups, their investigation opens the road to a series of researches the value of which can not be overestimated. Research, however, must be preceded by a conceptual viewpoint and imagination.

THE WHALER AND THE TORTOISE[1]

By Dr. CHARLES HASKINS TOWNSEND

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THE Elderly Whaler and I sat in front of the Old Doelen at The Hague smoking, enjoying the long summer evening and discussing the day's proceedings at the Court of Arbitration.

At the afternoon session I had made some statement relative to the extermination of fur seals at the Galapagos Islands, which moved The Whaler to talk about his voyages in that part of the Pacific. The fur seals had about disappeared in his "day," but the whaleships were still calling at the islands for supplies of tortoises just as they had been doing for sixty years or more.

When he found that I too had been there in search of tortoises his reservoir of reminiscence began to overflow. We pulled our chairs farther out on the wide brick pavement away from the chatter about the entrance and took turns at tortoise hunting until the belated stars came out.

The next evening after some preliminary harpooning of "sparm" whales, I managed to put the helm over and we made the islands again, it being my turn and tortoises more in my line just then than whales. It was in '88, I told him, that the *Albatross* cruised there and finally sailed with eighteen of the long-necked and hard-shelled "galapagos" wandering about the deck, one of them big enough for the sailors to ride. When I went there again in '91 we found only one. They are all now in the National Museum, victims of their first northern winter.

But my tortoises were no match for his three-hundred-pounders. So I filled my pipe and contentedly settled down to learn about those of his day, when some of the giants like those described by the early navigators were still to be found. All the "blubber hunters" cruising in the eastern Pacific went to the Galapagos Islands to load up with tortoises, mostly those small enough to be carried on a man's back, weighing say seventy-five pounds.

When larger tortoises were taken they were slung on whaleboat oars and toted by two or even four men. Sometimes a really big

[1] The New York Zoological Society will shortly publish a lengthy account of the giant tortoises of the Galapagos Islands in their relation to the whaling industry of the nineteenth century. It is based on the hitherto overlooked records of the whaling fleet as contained in many logbooks recently examined by Dr. Townsend.—THE EDITOR.

galapago, when found near the beach, was overturned and dragged by ropes tied to his legs. All the larger islands had tortoises, and whaleships might stay a week or more to lay in a supply. They required no food or water and lived on the decks for months.

The Whaler knew them as terrapin, in distinction from the long-flippered sea turtles, but always called them "turpin." My inquiry as to whether they were really as good eating as all the early navigators had claimed brought forth a most emphatic affirmative. There was *no* better eating than turpin, and as for turpin liver, when he was before the mast he noticed with great depression of spirits that most of it went aft to the cabin. But he had experienced its heavenly delectableness both then and later on when he occupied the cabin himself. Turpin fat was almost as wonderful. It made the very best of shortening. They took some of it home to the housewives of New Bedford and Nantucket, who pronounced it superior to anything known for that purpose and wished they might have more of it. Whaleships weren't as a rule oversupplied with high-class provisions. One Christmas day at sea he had doughnuts fried in turpin oil, the bright memory of which remained untarnished after half a lifetime.

The Whaler said that sometimes three or four whalers would anchor at an island and send men "turpining" from a camp on the beach. Men often got lost, and it took a lot of time to find them. More rarely a man that had wandered too far into rough country and got lost among the deep gullies and cactus, or was laid out by the heat, couldn't be found at all and had finally to be abandoned. There were cases where lost Crusoes, if they had succeeded in finding water, were picked up by other whalers after weeks of solitude. There were things ashore a man could eat, but he'd be "a sight" by that time. They always took water ashore. It was hard going for the turpin hunters over the terrible volcanic country. Didn't I find it so? I related my experience: One day I found a fifty pound tortoise a mile or more inland on Duncan Island and at an elevation of five or six hundred feet. It was past noon and my canteen had been empty for an hour. The heat could be described in nothing but superlative terms. I dreaded a return by the fearsome, cross-gullied route struggled over going in, but it seemed risky to seek a better one out with the handicap of a clumsy burden. The tortoise slung on my back by his legs exhibited signs of discomfort that did not lessen my own and the sling ropes fairly cut into my shoulders. Nevertheless it had to be carried. In my late day a Galapagos tortoise had become a rare natural history specimen, too valuable for any naturalist to abandon under any circumstances.

The bad going was the real barrier to progress. There was no sign of a trail and no straight course at any time for more than a few yards. There were patches of cactus, thorny shrubbery and broken lava blocks of uncertain balance to be avoided at every turn. There were missteps that did my shins no good, but hob-nailed shoes helped to save the situation. The general direction offered no problem, although the ship had been out of sight since eleven o'clock.

It was a course of difficult descents into hot narrow gullies, with more difficult ascents that necessitated frequent rests on the sharp ridges between them. When, after a course so necessarily devious that the distance was doubled or trebled and the ship finally located, the burden could be supported no longer. Securing the unhappy tortoise by one foreleg to the swaying branch of a tough bush and marking its position with the most of my shirt raised on the longest stick that could be found, I set out for the rocky shore a quarter of a mile farther down. Thirst, which was now approaching the maddening point, drove me into the sea, sweated clothing and all. This served at least to lower the temperature until the dinghy came. The boat's breaker being empty, the sailors put me aboard the *Albatross* for water before going for the tortoise, which they did not get down until sunset.

I suggested that possibly my tale of a tortoise hunt told after the lapse of years might be a composite of experiences on several islands, but The Whaler agreed that the difficulties of Galapagos travel were none the less real. Had it been otherwise, the supply of tortoises could hardly have lasted, as it did, throughout the long period of whaling activity.

One evening The Whaler and I drove to Scheveningen and after dinner at a big hotel sat watching the moonlight on the surf. I was still eager for the information he possessed and led the talk back to the subject of the tortoises for which the Galapagos Islands are chiefly celebrated, and whose mysterious origin and development on uninhabited volcanic islands have fascinated and puzzled all naturalists.

Darwin saw them in the days of their abundance and wrote by far the best account of them. I had carried Darwin's "Voyage" to the islands and The Whaler said he would read it when he got back to New Bedford. The Whaler got to the tortoise islands a quarter of a century after Darwin, but yet a quarter of a century ahead of me and saw things that I arrived too late to see. Many of the early navigators who went there in the seventeenth and eighteenth centuries wrote accounts of the tortoises and how they had carried them away by the hundreds. I had looked them up to some extent before going there myself, but I had never realized the

importance of the tortoises to the great whaling fleet of the nineteenth century. It was known in a general way, but had, strangely enough, never got into the books. The Whaler told me there were hundreds of vessels in the fleet at one time. While they didn't all go to the Galapagos or even to the Pacific, those that did so made repeated visits to the islands. It was their rendezvous for the wonderful turpin food that could be had for the taking. There was a great advantage in turpin meat in provisioning a ship. It could be had fresh any time at sea, provided they got plenty of them. It didn't have to be pickled, and nobody ever got tired of it. They took on board all they could get without too great delay—sometimes a hundred or more. Some ships that didn't expect to return that way took twice that many. The turpin lived in the hold among the oil barrels just as well as on the deck. The Whaler knew of some that lived more than a year and seemed to be as fat as ever. Certain skippers had in fact taken them to the home port and turned them out to grass, where children rode on them.

I told him that Porter, whose warship drove the British whalers away from the islands during the war of 1812, wrote of taking on board between four and five hundred tortoises at one time. The Whaler thought that likely enough, as the older skippers of his day often said, there were thousands of them even on the smaller islands along in the thirties and forties. Some of them were of enormous size. He had heard of two or three up in the mountains of Albemarle Island too big to be moved, that had dates cut on their shells as far back as sixty or seventy years. The whalers who had seen them thought they might weigh seven or eight hundred pounds, but this he was disposed to question until I told of the great tortoise of Aldabra Island in the Indian Ocean that was known by naturalists to weigh over eight hundred pounds.

My personal experiences on the Galapagos, which I had visited twice, had resulted in the acquisition of considerable tortoise lore and I held my own with The Whaler fairly well, considering that I had merely gathered up the rare and scattered remnant of the tortoise legions on which he and his ravenous crews once feasted high.

There weren't many turpin left after his day, he supposed. The whaling business didn't last much longer either. Petroleum had been discovered, which ruined the price of whale oil, and the Civil War with the seizure of many vessels just about finished it.

I turned the talk back a couple of centuries: The early navigators had put on record a great deal about the tortoises and their marvelous abundance. They also did their share at carrying them away. Dampier, who saw the tortoises in 1684, said, "It is incredi-

ble to report how numerous they are." Little is known of what the buccaneers and the sealers who followed them did to the tortoises, and there are but few records of the hundred years' toll taken by passing merchantmen. The whalers that finally came to gather the cetacean harvest of the Pacific outnumbered them all and continued the decimation that had been going on for two centuries. Dr. Bauer, a naturalist who went to the Galapagos in 1891, thought that ten millions of tortoises might have been carried away from the islands since their discovery. The part of the whalers in the destruction was known vaguely, but no one had searched their logbooks and assigned them a definite place in the history of tortoise extermination. This, I reasoned from The Whaler's talk, was something that should be done and some time later I set about it in earnest. Among the logs examined in certain old whaling ports, I found seventy-nine belonging to vessels that had visited the Galapagos at various times between 1831 and 1868 and had carried off thirteen thousand tortoises.

This afforded a measure by which to gauge the effect produced by the fleet as a whole, which once numbered over seven hundred vessels. Moreover, the limited number of logs discovered were those of American vessels only. What tortoise history might lie concealed in those of Great Britain and other countries formerly engaged in whaling about the Galapagos could only be conjectured.

The extracts from the logs supplied data respecting tortoises that had previously been lacking, giving not only the dates and the separate islands visited, but in most cases the numbers of tortoises secured at each. As each island of this anomalous archipelago bore its own particular species of tortoise, the most of which are now extinct, the logbooks of the whalers furnished new information on the progress of the work of extermination. According to these records, tortoises were taken from nine islands of this group, the smaller and lower islands being the first to be stripped of their stocks of tortoises.

Albemarle, the largest, with a length of seventy-five miles and elevations up to five thousand feet, continued to yield tortoises to energetic whalers long after they had become scarce elsewhere. Some vessels made large catches especially in the thirties, the ship *Isabella*, of New Bedford, heading the list with 335, taken at Hood Island from December fourth to eighth in the year 1831. The ship *Hector* took 237 at Charles Island in December, 1832; the ship *Lima*, of Nantucket, 224 from James Island in 1837, and so on.

Here are the quaint log entries on tortoise gathering from three of them, and most of the seventy-nine are quaint enough. I found that all the whalers called them turpin.

Ship *Abigail*, of New Bedford, at Indefatigable Island in 1834:

May 15 steering for Porter's island [Indefatigable] 4 PM came to anchor in Downes Bay in 7 fathoms
May 16 Boats came on Board with 21 large turpin
May 17 Boats came on Board with 31 turpin
May 19 Boats came on Board with 40 live turpin
May 22 the Boats Returned with 40 live turpin we got here 140 Terepin

Ship *Bengal*, of Salem, at Charles Island in 1834:

Mar 22 at sunset arrived on board the boates got 50 turpin larg an small, Mar 24 at 4 AM all the Boates whent a boute 12 miles to——N W point of the Island after anchoring the Boates we landed on the rocks and by the help of a rope we succeeded in getting up the precipice we found a plain with some large terrapin on of which & Backet to the Boates——we got 50 turapin

Ship *Barclay*, of New Bedford, at Charles Island in 1835:

July 15 at daylight sent 2 Boats for Turpin.
July 16 at 6 Boats returned with 20 Turpin.
July 17 2 boats a turpining——three of the men Deserted Caleb Halstead Alfred Overtwin Ron Blanchard the boat returned without them at 7 oclock the Boats Returned with 30 turpin.
July 18 caught the three Runaways put the Ringleader Caleb Halstead in Irons and kept him Below the *Gideon Basto* [*Barstow*] Left and the ship *Washington* and *Balcaner* of New Bedford Arrived

The *Barclay* was an old-timer, having made her first voyage in 1795.

But I have gotten far away from The Hague in telling about what I learned much later from the logs. The Whaler was wondering how the turpin got there in the first place, the crater-covered islands, one of them with a living volcano, lying five hundred miles from the mainland. The best I could do was to give him a choice of theories. A few naturalists were inclined toward a theory which presupposed a former land connection with the American continent. This would require, as Milton says, "a bridge of wond'rous length." Moreover, there were ocean depths of two miles between that had to be considered. I was impressed with these depths, having participated in the sounding of them. A simpler and more acceptable theory was that of distribution by currents and winds. The islands, extending through a hundred and thirty miles of latitude, lay across the paths of the prevailing westerly winds and currents. Their position was such as to favor the accumulation of drifting objects. With such conditions prevailing through a long period of time, various forms of living flotsam from the mainland could not have failed

to arrive there. The hardy tortoise, able to live for months without food or water and able to float, would have as good a chance to survive the voyage as the lizards or any of the early involuntary immigrants that had no power of flight. The Whaler and I had both seen plenty of drifting trees that could support animal forms and both of us had experienced the force of the currents setting toward the Galapagos. While there was no evidence that the islands were known to aboriginal man, there was also no evidence that he had not been there temporarily and taken a few mainland tortoises with him. The mainland tortoise was still to be found in abundance no farther away than the Isthmus of Panama. Although seldom more than two feet in length, it differed little more from the average Galapagan animal than did the various island forms of the latter from each other. If not their ancestor, it ought to be at least their first cousin.

When The Whaler's work was done and he had left for home, I am bound to say that I missed him. I have ever appreciated competent seamanship. Besides, he had given me the clue to the missing later history of the tortoises that I then and there determined to follow up. The logbooks of whaling vessels ought to contain records bearing on the long work of extermination that was now so nearly completed. Years later I went to New Bedford in search of them. My fine old whaler had gone where there are neither ships nor whales, except for Argo and Cetus in the starry vault overhead. What he had told the august arbitrators at The Hague from time to time about the business of whaling, they had never been disposed to question. So I observed in going over the scrawled and stained logs discovered at New Bedford and Salem and Nantucket that what he had told me about whalers and giant tortoises was verified in all the records that I found.

THE HUMANIST AND I[1]

By Dr. PAUL R. HEYL

THE BUREAU OF STANDARDS

My friend the Humanist has just been in to see me and we have had a royal good time together. It included our customary quarrel. No such occasion would be complete without that; we have been doing it so long. It started in our junior year in college, when we were called upon to make for the first time an election of the courses we proposed henceforth to follow. He chose the humanities and I the sciences.

I well remember how upset he was when he first heard of my decision and what he said about it. "And thou too, Brutus!" Of course he used the Latin for it. Anything else would have been beneath the dignity of a scholar of twenty. I started to reply appropriately, using good Shakespearian English. I got as far as "Not that I loved Caesar less," when he cut me off impartiently.

"Nonsense; I'm not worth considering. It isn't that; it's what you are giving up and what you are giving it up for. What has come over you?"

"Good gracious, my dear fellow!" I said. "Why do you take it so hard? I'm not electing a life of crime; I'm only going in for the sciences. Why not?"

"Yes," he said, somewhat more calmly. "I know the usual argument. Somebody has to do it. Our civilization is going to be more and more dependent upon the development of the sciences. And it's all true. But leave that to people who can not do anything else. Come back, and go with me!"

We had more argument back and forth on the matter which touched no vital point, but merely blew off steam, and we finally were each of the same opinion as at the beginning.

I felt a little hurt by his attitude. The sciences seemed to me to be equally as respectable as the humanities, only, of course, they had not as long a learned pedigree. They lacked the authority that tradition might confer. Such tradition as was theirs was even against them, for had not our sciences descended from such forbears as alchemy, astrology and black magic, practiced, oftener than not, by quacks and charlatans? But, equally, some of the

[1] Published by permission of the director of the Bureau of Standards of the U. S. Department of Commerce.

greatest humanists of old times were little better. Had not we read together, in our sophomore English, of Browning's bishop, ordering his tomb at St. Praxed's, with his love of good Latin, and "brown Greek manuscripts," with his exquisite taste in stone and sculpture, all superposed upon a personal character of an intolerable type? And had not the instructor quoted Ruskin to us as testifying to the accuracy of Browning's picture, saying that this short poem more truly and completely expressed the soul and body of Renaissance culture than all he himself had said in "The Stones of Venice"? And then, too, I knew that my friend was not ordinarily attracted by tradition and authority, that he set small store by pedigree and family tree, and that he had always chosen his associates for their own values. No, it must be that he held the sciences in low esteem on their own merits, and why I could not see, nor could I get him to specify.

I suspect now, after thirty years, that my friend was not exactly clear on that point himself, that his feeling of repulsion was largely subconscious and instinctive. Be this as it may, he held to his opinion and I to mine. Years, and the larger experience of life which they bring, have in some measure clarified the situation. In our perennial arguments we have been able to give each other more of a reason for the faith that was in us, yet neither has been able to convince or convert the other.

I once tried to tease him by saying that his dislike for the sciences was due to the exactness of thinking that they required, but I did not get very far that way. He parried that thrust easily, and without feeling it necessary to defend the humanities in that respect. "No," said he, "In some things exactness of detail is called for; in others it is an artistic fault. Consider the oil painting; by their reactions to it ye shall know them, whether novice or connoisseur. To the former the crudeness of detail is the most impressive feature, while the latter, at the correct distance, is unconscious of it."

And I suppose he is right. Where should we be without those who possess the great gifts of intuition and perspective? Did Shakespeare acquire his knowledge of human nature by a study of the psychology of behavior?

My friend's real aversion to science and its works and ways seems to be something else, something with which one must feel sympathy; a vague fear lest the scientific attitude of mind, logical in season and out of season (for there is a closed time even for logic), always schematizing, ordering, classifying, house-cleaning, putting things uncomfortably to rights—a fear lest all this leave no room for freedom of the spirit, spontaneity of mind or for the

priceless intangibles in general. It is the same sort of instinctive dread which the spiritually minded man may feel for the atheist; a fear lest he shall have taken from him something which he holds most precious and lest his outlook be reduced to an intolerable grey monotony.

Such regard I, an insider, have never felt that scientific men have deserved. I have learned that the pursuit of science demands imagination to a degree which few persons are fortunate enough to possess. The better poet, the better man of science; and I can prove this by the evidence of the poets themselves. The hushed awe of the Psalmist before the starry heavens; the flower in the crannied wall, sending down its roots deeper than did ever plummet sound; the solemn organ tones of Thanatopsis, telling how Nature answers in a varied language, now gracious as a queen's greeting, now inscrutable as the Sphinx—what are these but recognition on the part of the poets of the essentially spiritual and artistic quality of the subject-matter of science? And if the world has gained the impression that science is grim, whose fault is it?

Ours, of course, we high priests and prophets of that faith; but it takes usually many mellowing years before one can see this. I suppose that in my green olive days I contributed my share toward this general impression, and I do not now blame those who seemed disinclined to acquire the taste for the unripe article. But advancing years should have softened the high intolerance of youth in my friend the Humanist also; and this is now my principal quarrel with him.

I think, however, that I made rather a dent in his armor this evening. Looking over the books the other day at a second-hand stall I found a volume of essays. One of them was on "Sun Worship." In its pages my eye caught something. "Ammunition!" I said, and took the book home with me.

I admit that I set the stage when I knew my friend was coming, but I plead the end as justifying the means. When he entered I had open before me a certain book at a page containing the maximum number of mathematical symbols that I could find. He cast a rather contemptuous glance at it as he sat down.

"Come, now," I said. "You are not fair. You did not let Greek characters keep you from the thought that was behind them; and I do not think you would turn up your nose even at a page of Arabic if you thought there was something worth while in it. You might regret your unacquaintance with Arabic; in your ignorance of science you glory. This contempt for the language in which my books are written goes too far. Your attitude, old fellow, carries

with it an implied insult to my intelligence as a student of such matters."

He grinned at me in return.

"That's just what has puzzled me all these years. What is there behind these cabalistic runes that could interest a certain young fellow I used to know?"

For answer I pointed through the window at the sinking sun. He looked bewildered. "Come," I said, "Let me translate for you." And muttering under my breath, like Huxley, "The Lord hath delivered him into mine hand," I took down my recently acquired ammunition and read to him from one of the pages:

THE PSALM OF THE SUN

Bow down, O my children: even worship me, ye men of wisdom!
As I rise upon you, and ye greet the morning: humble yourselves and be thankful.
For all that man possesseth is of me: and what hath any man that I have not given him?
Should I withhold my glory from the fields: or should I turn away from the watery mirrors,
Where then were the fruit of the earth: and where the dew of the morning?
Therefore rejoice, O my children, in my bounty: and bathe yourselves in my glory.
As I rise upon you and ye greet the morning: humble yourselves and be thankful!

He was silent a moment; then he picked up the book lying on my desk and looked at it. The title of the chapter was "The conservation of energy." On the fly leaf he saw my boyish signature and the date—our junior year in college. He looked at it for several moments; then he laid the book down (rather carefully, I thought), saying:

"And they never told me!"

RADIO TALKS ON SCIENCE[1]

COAL

By Dr. DAVID WHITE

U. S. GEOLOGICAL SURVEY

COAL is like character; the deeper you go into it the more interesting it becomes, and there is much in it that, unsuspected, is beautiful. Ordinary bituminous coal is dirty, black and uncouth, and anthracite is none too clean; but if you cut from a lump of coal a slice thin enough to be translucent and examine it under a microscope you will see what beautiful things coal is made of.

The preparation of such a thin section is a most delicate task. First, a thin flat piece from a lump is sawed out and then ground down smoothly until it is reduced nearly to a film—that is, until it averages about two ten thousandths of an inch in thickness. This thickness—or rather thinness—would correspond to the leaves of a book in which fourteen thousand pages make a volume only one inch in thickness. The thin slice of coal is then mounted on a thin piece of glass for study.

Seen through the microscope such slices of coal are found to be translucent, and if treated with certain chemicals before grinding, they will be so beautifully translucent that they may be examined by a microscope which magnifies them more than eighteen hundred times.

Under the microscope the coal is no longer dark as night, or sooty, or forbidding. In the cross-section of that dirty lump one beholds a landscape in brown and gold. Golden links in serried chains bound in filigree fill portions of the view. The links are the cross-sections of the cells of pieces of wood of twig, branch or log that enter into the product we call coal. Each cell in the wood is a jewel box of gold. In the hollow interior where once were protoplasm, starch and other substances embracing the very life of the plant, we find a transparent amber-like substance clouded with sepia and containing clusters of shining crystals of utmost minuteness, together, perhaps, with tiny glistening globules of gas. Stem of leaf and fern and scale of catkin or cone are seen in tissues traced in saffron and orange, straw-color and russet. Scattered

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of Mr. W. E. Tisdale.

here and there are a thousand spores of club moss, fern or fungus, and pollen of many kinds of flowers, now appearing as ovals, clasps and crescents of luminescent brass or antique gold. Festooning skeins in brown, knit with silver representing cross-sections of fragments of inner tissue of leaf or bud are perhaps present; and resins of different kinds, brownish, amber, yellow and red, stud the pattern like precious stones. Real amber used in jewlery is, you know, a fossil resin. Yonder mesh of old gold sealed over with a mosaic in glistening topaz-yellow is a piece of the outer wall of a leaf. The fragile labyrinths traced in pale yellow and silver are the cross-sections of fragments of "mineral charcoal," the so-called "mother of coal." The scene changes from area to area and from specimen to specimen.

All these details of tracery and mosaic are set in a background—the ground mass—of cinnamon verging into sepia and brownish black, which fills the spaces. This composes the dark shadows of the picture.

All this vegetable débris which we see under the microscope corresponds exactly to that which we know as peat as it is formed to-day in some peat bog; and though this débris in coal is now fossilized and its chemical composition is greatly changed, it does not differ either in structure or nature from common peat. In fact, the close geological as well as the microscopical study of coals proves that all the ordinary kinds of coal, including anthracite, began their existence as peats deposited in vast swamps that once spread back of the low coasts, or in the interior lowland basins of the continents in ancient geological times.

These ancient peat swamps were usually covered by forest growth, and the coal beds, as we now find them, are generally underlain by old soils in which the roots of trees and smaller plants are still seen where they grew. Most of the swamps were very shallowly covered by water during parts, at least, of the year, just as now are the great peat swamps of the south Atlantic states. The botanical evidence points toward mildness of climate with ample rainfall, especially when and where the earlier coals (peats) were laid down in the Appalachian coal fields.

What we see under the microscope, namely, wood fragments, twigs, leaves, seed coats, spore cases, etc., now chemically transformed in colors of gold and brown, are, of course, the plant débris that was saved from decay by the germ-poisonous products developed by bacteria at or near the surface of the peat on which this débris was deposited. Decay, largely the work of the microorganisms themselves, ceases in the peat. Many of the plant compounds, including the protoplasm in the cell cavities, were broken down by

the bacteria at time of deposition. Most of the delicate tissues and even portions of the wood generally underwent more or less decomposition—that is, chemical change—in this process. However, the great chemical and physical transformations by which the peats were changed to coals of successively higher ranks—*i.e.*, lignite, sub-bituminous, bituminous, semi-bituminous (or smokeless coals) and anthracites have been brought about by geological processes instead of by bacterial action. The principal agents in the geological transformation are pressure, heat and time.

The pressures taking part in the conversion of peats to coals of different ranks are, first, the downward pressure or weight of hundreds—perhaps many thousands—of feet of beds of sand, mud, limestone, etc., piled on top of the peat bed as the region was sinking or the basin was filling. Second, and far more effective, however, are the horizontal pressures which cause great lateral compression of the rocks, and in certain regions produce buckling or great wrinkles in the earth's crust—*i.e.*, the building of mountains. Pressures overcoming the strength or rigidity of the strata of the crust cause breaking and faulting, as well as buckling. Continued thrust ramming after the strata are broken or highly folded drives the beds on one side across the broken edges on the other side and onward in a great overriding wedge or overlap. Such overthrusts are unnumbered. They date from different geological periods and occur in many regions, and some are now in progress. In Glacier National Park, Chief Mountain is carved from a great overlap of very ancient beds of limestone that have been shoved eastward at least ten miles over on top of soft Cretaceous rocks that were formed more than two hundred millions of years later than the limestones. The entire Cumberland coal basin of southwestern Virginia and northern Tennessee has been driven several miles westward on to the eastern Kentucky coal field. Arthur Keith, of the U. S. Geological Survey, the highest authority on Appalachian geology, calculates that the earth's crust between Cincinnati and the Atlantic coast was formerly over 200 miles longer than it is now; that is to say, these two points have been brought that much nearer to each other as the result of the horizontal pressures, towards the west, of the earth's crust near the Atlantic coast.

Most earthquake zones are the scenes of compression and mountain building, though the movement is invisibly slow. The coals have progressed farthest on the road to anthracite and graphite in those regions where the greatest actual horizontal compression of the strata including the peat beds has taken place.

The temperatures developed in the process are those due to depth of burial of the deposit—say 1° F. to each eighty feet down-

ward through depths averaging about two thousand feet, plus the heat generated by friction due to the compression, through millions of years, of the rocks as just described, and finally, the heat caused by chemical action in the buried strata. Altogether, however, the temperatures in the coal beds were probably less than 300° F. in most coal regions. Comparative lowness of temperature is, however, compensated by great length of geologic time, time and temperature being, in fact, partially interchangeable in the geological transformation of coals.

To illustrate: In portions of the state of Washington relatively young coals, of an age probably not less than nine million years old, have through drastic compression—forced marches, so to speak—been brought to the same stage of evolution as the coals laid down perhaps a hundred million years earlier in the Appalachian and mid-continent states. Some of these Washington coals and some in Colorado that may be twelve million years old are changed even to anthracite. In Rhode Island the peats which grew at the same time as those in Pennsylvania or Arkansas have been changed nearly to graphite. They can be burned if one tries hard enough, but they are at present much more useful as facings in molds for casting iron than for fuel. The well-known metamorphism of coal by contact with hot or even melted rocks that have risen from great depth in the earth's crust is essentially local and relatively unimportant.

The amounts of carbon, hydrogen, oxygen and nitrogen in any coal as a whole can, of course, be determined by the chemist, but very little is known as to the multitude of chemical combinations of these elements which must exist in it. They change more or less from rank to rank of the coal. In burning coal, nearly all the heat is furnished by the carbon and hydrogen, the oxygen being about as objectionable as water or ash. Fortunately, the oxygen, which composes nearly half of the solid plant matter at the start, gradually is driven off so that the coal improves steadily until it passes above the semi-bituminous stage when, on account of rapid losses of the hydrogen, which per unit produces three times the heat of carbon, the heating value of the coal drops off notably in the anthracites. So, in the midst of the dirt, soot and less healthful environment in which we are forced to live in response to anthracite strikes and the exhortations of government bureaus and engineers to burn soft coals because they are cheaper and plentiful, the solitary ray of comfort that comes to us is the greater heat given by these coals. Washington was once the city beautiful and white.

Coal is still the world's greatest source of industrial power and it will remain so for a long time, for the coal reserves of the world probably exceed 10,000 billion tons. Our portion, over 3,500 billion tons, of these vast supplies, should last us many centuries in spite of increasing population and expanding industries, though our coal exportation probably will not grow correspondingly. The actually depressing feature is that we are rapidly mining our limited reserves of best and most valuable coals first. It will be no long period before our so-called smokeless or Navy coals will be largely consumed, and we shall be using inferior and generally dirtier coals mined from thinner beds, at greater depth and at greater cost. Our anthracite reserves, the years of which are said to be numbered, are already put upon a conservation basis of what our friends the economists call "reservation for the highest purposes" which in this case seems to mean the poorest coal for the greatest number. The small consumer, who is mostly the householder, does not buy his coal on specifications.

Coal fields occur in every continent and in nearly every country of the earth. Coal beds, thick and pure, are found above the old soils on which the plants grew in the Antarctic continent as far as 80° S., and in most of the lands surrounding the North Pole. Thus, they occur within 9° of the North Pole in Spitzbergen and Franz Joseph Land, and are present also in the northernmost islands of British America and in Nova Zembla.

Curiously enough, in any geological period the coals laid down in the Arctic regions were in general formed from the same sorts of vegetation, and to a great extent from even the same genera and species, including trees of large size, as were the coals formed during the same periods, in the swamps of West Virginia, Colorado or Washington. There is food for thought in the extraordinary north-south distribution of some of our ancient coal-forming trees, shrubs and ferns—the occurrence, for instance, of the remains of fossil forests beneath the ice of Antarctica, and about 15° beyond the Arctic Circle in Franz Joseph Land.

FOODS DISCOVERED WITH AMERICA

By Dr. WILLIAM E. SAFFORD

I WONDER how many of those who are listening to-night realize that the plants of our gardens, the cereals of our fields and the fruits of our orchards were developed from wild plants, many of them by primitive tribes, before the dawn of civilization; among

the American plants maize, from some native grass; potatoes, from a wild nightshade of the Peruvian Andes; sweet potatoes, from a fleshy-rooted morning-glory; beans and lima beans from wild twining plants growing in thickets; pumpkins and squashes from trailing gourds, probably bitter and uninviting in their wild state; tomatoes and red peppers, from wild plants, with inferior fruits, growing on hillsides and plains of tropical America. From classic writings of the Greeks and Romans we learn something about the principal foods eaten at their feasts and of the plants cultivated in the gardens and groves of the Mediterranean region. From early Sanscrit, Chinese and Arabic writings we derive a knowledge of the principal foods of Asia. From these and from ancient herbals we can form a complete list of the food plants used before the discovery of America, in the Old World the origin of many of which is lost in antiquity.

To-night I shall speak of the food plants of ancient America, developed from wild species by the Indians, all of them strange to the discoverers and explorers of the New World. It was in quest of food products that Columbus set out upon his memorable voyage. He may well be called the pioneer of agricultural explorers. He had no idea of discovering a new world. Convinced that the earth was round, his object was to find a short, westerly route to the lands described by Marco Polo and other early writers, especially to the Spice Islands, from which he hoped to bring back a cargo worth its weight in gold. Before embarking he provided himself with samples of cinnamon, cloves, peppers, nutmeg, ginger and the fragrant aloes wood, which is burned as a perfume in temples of the Orient. After reaching the West Indies he exhibited these samples wherever he landed, indicating by signs that such substances were the object of his search. When the natives appeared to recognize some of them, he imagined that he had indeed reached his destination and so reported to his patron, the King of Spain.

In the narrative of his voyages notes were made of the various foods encountered, and this information was amplified by Las Casas and later explorers, so that the identity of the plants mentioned by him became well established.

The first foods encountered by Columbus were two thick roots which he called *niames*, or *yams*, a name applied to somewhat similar roots growing in Africa. Later entries in his journal describing a kind of bread called *casabi*, made from the larger of these roots, identify it at once with the manioc, or mandioca, from which the tapioca of commerce is derived. The second root, called *ahe* by the natives, having a delicious taste of chestnuts, proved to be the sweet potato.

It is not possible, to-night, to enumerate all the food plants encountered by the early explorers of the West Indies. Most of them, it is safe to say, had been brought from South America by the aboriginal inhabitants of those islands. Among them were Indian corn, or *maize;* beans, quite distinct from the European faba; peanuts; red peppers; Carib cabbages, resembling the taro of Polynesia; among the fruits, guavas; various species of custard apples, including sour sop, sweet sop and bullock's heart, allied to our so-called paw-paw; the true paw-paw, or papaya, whose soft, upright stem was used by the Carib children as a target for their arrows; grenadilla, or passion-flower fruit; and, best of all, the delicious pineapple, which Columbus encountered on his second voyage. Such fruits as oranges, lemons, apples, pears, peaches and bananas were lacking. Certain fruits resembled plums, but they were quite different from true plums and were borne on plants botanically allied to the mango of the East Indies.

It may be well also to mention tobacco and cotton, as found in these islands, the latter belonging to the species from which our best long staple cotton has been developed, quite distinct from the Asiatic cottons from which the calico of Calcutta and the Chinese nankeen were woven.

Turning to Mexico, I shall have no time this evening to tell of the wonderful gardens of the Aztecs, described by Cortez in a letter to his king. It will be sufficient to say that maize, or corn, red peppers and beans were the chief food staples of the Mexicans, while their greatest delicacy, chocolate, was made from the seeds of cacao and flavored by vanilla, extracted from the fruit of an orchid which climbed the forest trees of Vera Cruz; and by a spicy flower called *ear flower* from the resemblance of three of its petals to the human ear.

From the agave, or century plant, the Indians of Mexico and of our own southwest derived sugar, vinegar and a fermented drink; and from prickly pears and other cactus plants, sweet syrups and various kinds of marmalades. The Mexicans also cultivated sweet potatoes and tomatoes. One of their best fruits was the avocado, recently introduced into the United States. Their principal tobacco was a yellow-flowered species, quite distinct from that of the West Indies, but identical with the tobacco cultivated by the North American Indians east of the Mississippi River. One other aromatic product of the West Indies and tropical Mexico should also be mentioned, the allspice, which grows on a tree closely allied to that which yields the fragrant oil of bay rum.

In South America, the Portuguese in Brazil and the Spaniards in Peru and Chile found in cultivation nearly all the plants I have

mentioned, the principal food staple in Brazil being the manioc, or cassava plant, and in Peru maize or Indian corn. Each of these countries had species of cotton allied to but distinct from those of the Antilles and Mexico.

In Brazil was also found the arrowroot and, growing in the terraced mountains of the west coast and on the great plateau of Bolivia, the so-called Irish potato, perhaps our most important heritage from ancient America. In the mountains of Peru were also found the cherimoya, most delicious of all the custard apples, and the aracacha, an aromatic celery-like plant which would undoubtedly have been more widely cultivated in the New World if we had not the introduced celery itself. In Paraguay the most important plant was a species of Ilex, or holly, from the leaves of which a stimulating tea was prepared, now commercially known as *yerba mate.* In Florida a similar tea, called cassine, was prepared from a closely allied species, which took the place of China tea, when that was lacking, and was used in the celebrated Black Drink of the Indians of southeastern United States.

In North America the early colonists found the Indians of the Atlantic coast, from the Carolinas to Canada, cultivating, in addition to corn, beans, squashes, pumpkins and tobacco, the sunflower for the sake of its oil-yielding seeds and the closely allied Jerusalem artichoke for its fleshy tubers.

In addition to the cultivated crops there were other plants growing spontaneously in the marshes and forests; some of them, like the yellow-flowered lotus, arrowleaf and Virginia arum, botanically allied to important species now cultivated in the water gardens of Asia. To these must be added the wild rice, from which the Menominee Indians take their name, and the Indian potato, or marsh potato, a tuber-bearing plant called *openauk* by the Algonquin Indians, from which certain tribal clans and villages were named.[1] It would have been hard for the early colonists, if they had had only cultivated crops to depend upon. When there was dearth of food in Virginia and New England, they were driven to eat the wild products of the swamps and woods. Of the Virginia arum, called "tuckahoe" by the Indians, Captain John Smith declared that raw it was no better than poison, and that it "tormenteth the throat," a remark which might have been made of the allied taro of Polynesia, or the Carib cabbage of the West Indies, which sting the mouth with microscopic needles embedded in their tissue,

[1] For illustrations of this plant (*Glycine apios*) and its strings of roots see "The potato of romance and of reality," in *Journal of Heredity,* Vol. 16, plates 4 and 5, April, 1925.

like the Jack-in-the-pulpit or Indian turnip of our woods; but which, when properly sliced, dried and cooked, was an important food staple of the Indians.

The most important of all the forest trees was the maple, from the sap of which the Indians made their sugar. Among the nuts the most important were the pecan and the hickory nut, from the latter of which a delicious creamy emulsion was made by pounding the nuts with water, in a mortar, straining out the shells and pouring off the surface water after the rich cream had settled. It was this substance, called pawhiccora, which gave the hickory nut its name. From hickory nuts and butter nuts delicious oils were made. Other products of the forest, including walnuts, hazel nuts, chestnuts and beech nuts, resembled Old World species, but differed from them specifically. The same is true of some of the berries, including strawberries and blueberries, from which we have developed such fine cultivated forms; also the wild grapes, from which have been derived our Concord, Catawba, Delaware and other hybrids. Another fruit quite different from anything in Europe, but with relatives in Asia, was the persimmon, which the Indians preserved by drying, and from which they made a fermented drink.

Jacques Cartier, during his exploration in Canada, in 1535, came upon Indians on the shores of Georgian Bay who were picking blueberries to dry for the winter. Other Indians in this region travelled about bartering sunflower-seed oil and tobacco for other commodities, and one of the early French missionaries describes how, forced by starvation, he went to the woods to dig Indian potatoes or groundnuts, which he called chapelets, or *rosary roots,* from their bead-like arrangement in strings.

What I have said of the resemblance of certain plants to Old World forms, from which they differ specifically, applies also to many animal foods of America. Thus the delicious Virginia oyster, upon which the Virginia colonists fed at certain seasons, is quite distinct from the European species. The lobster of the Atlantic coast, the spiny lobster, or crayfish, of the southern waters, and the more northerly scallops and clams, are all quite distinct from corresponding European species, and the delicious shad and pompanos of the western Atlantic are essentially American.

In concluding my talk I would like to present an American menu, somewhat similar to one served at a dinner given in honor of a visiting European botanist, composed entirely of dishes made up of foods discovered with America:

Cocktail of Virginia oyster, with sauce of tomato and red pepper
Chowder of little-neck clams, with tomatoes and green corn, with opossum fat substituted for pork
or
Terrapin stew, made with turtle eggs
Barbecued shad à la Indienne, with white potatoes; and tamales à la Mexicaine
Bell peppers or tomatoes, stuffed with wild rice
Turkey, stuffed with native chestnuts or oysters; cranberry sauce, sweet potatoes, string beans, succotash of lima beans and green corn, stewed tomatoes, Jerusalem artichoke, corn-pone or hoe-cake, guava jelly
Salted peanuts
Sherbet, passion-flower fruit à la Martinique
or
Sour-sop à la Havanne
or
Cherimoya à la Peruvienne

For the game course:
Quail, rice birds or canvasback ducks, blackberry or grape jelly
Salad of avocado (or alligator pear), with dressing of sunflower or hickory nut oil and maple vinegar, and cayenne pepper and salt
Pineapple tapioca
Pumpkin pudding
Stewed blueberries
Strawberries
Grapes, wild plums
Pecans, Brazil nuts, water chinquapins (or lotus fruit) hickory nuts, pine nuts, hazel nuts, popcorn
Chocolate—yerba maté—cassine tea
Cigars and cigarettes

Would any one go away from this dinner complaining of the lack of milk, eggs or wheat flour of the Old World?

CARLSBAD CAVERN

By Dr. WILLIS T. LEE
U. S. GEOLOGICAL SURVEY

After listening in with you on numerous occasions, it is a pleasure to stand at the other end of the air and bring to you, through the air, the news from an underground realm. This is a special pleasure because, as a former flyer, I abandoned the air to go underground and am now back on the top of terra firma—safe.

Carlsbad Cavern has nothing to do with Carlsbad in central Europe. It is situated in southeastern New Mexico in the valley of the Pecos River—not Arizona as announced in the newspapers.

This cavern has been known locally for a long time. But not until the news of its unusual character was received by the readers of the *National Geographic Magazine*, about a year ago, did the world at large know anything about it.

The discovery of the astonishing nature of this cavern was the result of examinations made of proposed reservoirs on Pecos River. The rocks which cause the reservoirs to leak contain the great cavern.

Following the first publication, the National Geographic Society sent an expedition to explore the unknown parts of the cavern. For nearly six months we were engaged in this work, and many interesting discoveries were made.

Carlsbad Cavern is the work of water. Like many another well-known cave, it was made by the solution of parts of the rocks. It differs from others in that the limestone rocks here contain beds of gypsum and rock salt. Through long ages the underground water dissolved and carried away soluble material, leaving a great cavity deep down under the highlands.

In the course of time this process was reversed and the water, carrying carbonate of lime in solution, deposited this material within the cavern in the form known as cave marble.

The solution formed subterranean chambers of astonishing size. Deposition decorated these chambers with adornments of surprising variety and beauty. Also deposition cemented together such loose fragments as may have existed and thus made improbable such tragedies as that of Sand Cave in Kentucky.

What Niagara is to waterfalls, Carlsbad is to caverns. It is king of its kind.

The National Geographic Society's camp was established at the mouth of the cavern, twenty-six miles from Carlsbad. This is a desert region, and the nearest spring is nearly a mile away. Water was carried by burro, and fire wood was "rustled" from the mountain side.

There was no refrigerator in camp and there were no shade trees. Sometimes the temperature reached 110° in the shade—and no shade could be found.

But the cavern is always cool. There we found a uniform temperature of 56° F. A small opening near the elevator shaft served in place of a refrigerator. Provisions lowered into this opening were kept cool and fresh.

Long ages ago bats learned that the cavern was a nice cool place in which to spend the hot days. Great numbers of them may be found in the cavern any day. But just after sundown they come out to spend the night on the wing, feeding on night-flying insects. Before dawn they are back again, each tucked snugly away in his chosen crevice or hanging head downward from the ceiling.

The bats did not approve of the National Geographic Society's activity. The lights disturbed their slumbers. As we passed through their chamber they circled about and scolded. Not knowing bat language, I can not translate their remarks, but I am sure they were not complimentary.

We never remained in the cavern over night. The cave air is damp. A slight extra effort started the perspiration, and relaxation was followed by chills. Clothing left below from day to day became damp and mouldy.

Our work in the cavern was done by the light of gasoline lanterns. Most of the time was spent in chambers nearly eight hundred feet beneath the surface, and a mile or more from the entrance.

The absolute darkness and the unbroken silence of these subterranean places affected the workers in different ways. Some feared the dark and frankly confessed it; others feared and were ashamed of the weakness. Some were attracted by the mysteries of the unknown; others clung tenaciously to the beaten path.

All who worked regularly in the cavern were under mental strain. Their nerves were "jumpy." There was much discussion about the possible collapse of the roof. The possibility of disaster affected the night dreams as well as the day dreams.

One night in the "wee small hours" a terrific commotion was heard and the men rushed out of the bunk house, exclaiming excitedly that the cave had collapsed. No evidence of the disaster was found. But a fresh disturbance back of the bunk house directed attention to old Pete, the burro that carried wood and water to camp. His feet were tangled in the wires of an old bed spring into which he had ventured too far in search of tempting bits of cloth, of which he is very fond. In his efforts to free himself from the wire entanglements, he had stumbled down the hillside against the bunk house, bringing with him several loose boulders.

The first work in the cavern was done on the trail. Rough places were smoothed out and such improvements made that we reached our work in little more than an hour's time, whereas it had previously taken more than two hours to go in and two to come out.

The chambers previously explored were used as points of departure for new discoveries. From them we pushed our way into the unknown parts.

Tom Sawyer was emulated in the use of kite strings. We used white twine, which was left as permanent markers. In time we had a system of avenues, with white twine markers leading to the exit.

Allow me now to take you on a personally conducted tour through this new wonderland. It must be a flying trip, for it would take days to examine all the strange features.

The cavern is approached from Carlsbad over a plain and up a mountain side to an opening where the roof collapsed. Near this opening a shaft has been dug and fitted with a windlass and wire rope having an iron bucket at the end. We climb into this bucket, the floor at the top of the shaft opens, and we descend 170 feet into the Stygian darkness.

After a little time spent in adjusting the lanterns and getting our "cave eyes" we take the trail, picking our way over and among great blocks of rock which fell from the ceiling.

We pass beneath the great opening where the roof fell 250 feet, climbing up and down and over and around blocks of rock in the spacious corridor with ceiling so far above that the lanterns only dimly illuminate it.

Three quarters of a mile from the entrance and more than eight hundred feet under the surface, we reach the roughest place on the trail. Here were found parts of a human skeleton. Some cave man had lost his way and perhaps fell from rock to rock in the darkness to the shelf where his earthly career was ended.

The spectacular part of the cavern begins just beyond this difficult part of the trail.

The first chamber to be entered is Shinav's Wigwam. It is nearly circular in outline, two hundred feet across, seventy-five feet high and wonderfully adorned. At the entrance to this glorified wigwam of the Navajo's wolf god hangs a large stalactite of gnarled appearance, which resembles a cave man's war club.

The wigwam is surrounded by alcoves and niches and tributary chambers of marvelous character and amazing adornment. Had the author of "Arabian Nights" seen Carlsbad Cavern, he might have enriched his tale of Aladdin and his lamp with facts stranger than the fictions used.

One of the most beautiful of these tributary chambers was discovered when one of the explorers crept through a small hole in the wall of the wigwam. The partition here is thin and a surprisingly spectacular view never before seen by human eye opened at once to his astonished gaze.

This new chamber was named Avanyu's Retreat for the wise serpent of Indian mythology, who is said to have lived in the waters of the underworld and who insisted on attending the councils of the gods.

An effort is being made to use in the cavern place names taken from Indian mythology.

We must not linger long in the wigwam, for the most spectacular part of the cavern lies beyond. To reach it we climb over a pile of rocks 183 feet high on the floor of an enormous vault whose ceiling rises 350 feet above the floor. The inner slope of this hill leads down through a decorated archway into the Big Room—a great

cavity half a mile long and surrounded with tributary chambers and corridors, alcoves and niches.

These tributary avenues were searched in the hope of finding an exit through which an easy entrance to the cavern might be constructed. The search led to many new discoveries—too many to be even mentioned to-night.

We succeeded in finding no outlet, but the survey proves that the end of the Big Room is only twelve hundred feet from the foot of the mountain. A tunnel driven into the mountain will lead directly to the spectacular part of the cavern. It is expected that this tunnel will soon be dug.

Some of the most interesting discoveries were made in the basement of the cavern.

A series of chambers was found ninety feet below the floor of the Big Room. The guide was lowered first on a rope through a hole in the floor. He had an unhappy time. In the uncertain light of his kerosene torch, things looked strange and unreal. All went well until he reached water in the fountain at the bottom of the hole. To his perturbed mind this seemed like an ocean. His frantic signals to be raised were misunderstood and he was dropped unceremoniously into the water. With light gone, he passed an unhappy moment in the darkness before he discovered that he could touch bottom.

Later a wire ladder ninety feet long was built and lowered into the hole. The lower seventy-five feet of the ladder swung clear of the wall. A wire ladder has an erratic disposition and an obstinate nature. Those who first descended swayed and spun about in the darkness. Those who possessed weak nerves had a sorry time.

The newly discovered chambers are extensive and wonderfully decorated. It is quite impossible to describe them. The only way that a realization of their marvelous nature can be secured is to see them.

Carlsbad Cavern is only one of many caverns in the Guadalupe Mountains. But this is another story!

JOHN BARTRAM, BOTANIST

By Dr. WILLIAM SHAINLINE MIDDLETON

THE UNIVERSITY OF WISCONSIN

The lower reaches of the Schuylkill, flanked by manufacturing plants and refineries, present a strange contrast to the "fine prospect . . . and rich meadows," which James Mease described in 1810. The present-day student of nature, unfamiliar with the historic past of this region, will find little incentive to a close acquaintanceship. Indeed, the murky skies and even murkier waters seem most forbidding to such studies and even to the opportunity for them. Yet on the right bank of the Schuylkill, near old Gray's Ferry in Kingsessing Township, John Bartram established the first botanical garden of consequence in America in 1730. The botanical gardens of the Rosicrucians and of Dr. Christopher Witt antedated the Bartram Garden; but in the case of the former only medicinal herbs were cultivated for the use of the brotherhood, whereas the latter garden had a rather limited influence in the advancement of botanical knowledge. So that in effect the current statement of the priority of the Bartram Garden is essentially true. The present state of the garden suggests its former glory as little as does the shell the living "Acada Septendecim" which Bartram so faithfully portrayed; yet here he labored with loving hands, gathering the native flora from the Great Lakes to the Gulf and from the Ohio to the sea; also nurturing the seeds and plants sent to him from foreign lands. From the Colonial period on, this garden spot played an important rôle in the life of Philadelphia. Here Washington, Franklin, Hamilton and Jefferson found peaceful repose from their arduous tasks in the capital of the new republic. Here Alexander Wilson, a drifting youth from Paisley, found an impetus to new endeavor and from the denizens of its leafy bowers drew the subjects which formed the first standard treatise on American ornithology. For him as for other frequenters of this charmed spot romance was abroad and he married a niece of his friend, William Bartram. Here students of nature and of art have through the generations found ample materials for instruction and reflection. And here Weir Mitchell, in characteristic strain, brought his hero, Hugh Wynne, for refuge and refreshment on his flight from Philadelphia. John Bartram and his garden interest us especially by reason of their botanical contributions.

Botany is "the eldest daughter of medicine." As John Bartram pointed out, primitive peoples in all ages have sought relief

from their physical ills by natural or the most available means. Herbs and plants of reputed medicinal value came into general or local use according to the individual and collective experience with respect to their efficacy. With the ascendency of therapeutic nihilism and, more rationally, under the scientific scrutiny of pharmacologic study, many of the familiar vegetable preparations of our forefathers have lost favor. Unquestionably much of the poetry of medicine departed with the passing from daily usage of hepatica, quebracho, euphorbia, convallaria, arum and a legion of other old favorites. No more does the physician lean for uncertain support on pleurisy root, snake root, wahoo, spikenard, black cohosh, burdock, meadow rue and juniper berries. Yet what physician is ready to discontinue the use of the deadly nightshade, foxglove, poppy and coca? The indebtedness of medicine to the vegetable kingdom is enlarged when the sources of camphor, nux vomica, cinchona, ergot, ipecac, kino, physostigma, chaulmoogra, glucose, saccharose and the salicylates are considered. If to these be added practically all the anthelmintics, carminatives, emollients, bitters, local counter-irritants, irritating laxatives and a large group of indirect derivatives of the vegetable kingdom such as alcohol, ether, coal-tar products and their kind, the overwhelming dependence of medicine on her neglected eldest daughter is in a greater measure appreciated.

To comprehend the low estate to which botany has fallen in the estimation of the medical world it is essential that its past position of honor be appreciated. The yoke of mysticism and spiritualism in the practice of medicine was only removed by the recognition of natural causes for disease and its expressions. The relief of disease and its manifestations was for centuries primarily a function of the priesthood who judiciously supported nature by the use of medicinal herbs and attributed both cures and failures to divine intervention. With the gradual divorce of medicine from the clergy it was natural that physicians should seek to fortify themselves by a superior knowledge of the medicinal properties of available herbs. In turn medicine was responsible for the early growth of botany as a science. Theophrastus of Eresus, in Lesbos (B. C. 372–285), was the first physician-botanist of note. He collected or described by personal observation and inquiry some five hundred plants. Dioscorides, a physician to Nero, was likewise a distinguished botanist. However, it was not until the sixteenth century A. D. that botany saw its greatest growth as an applied as well as an abstract science. In this period Valerius Cordus (1515–1544) and Andrea Cesalpino (1524–1603) made fundamental contributions to the systematic study of plant life. Cordus, in addition, compiled the first dispensatory which was adopted by the

Senate of Nuremburg in 1535 as the standard for their apothecaries and probably first printed in 1546, at the expense of the Senate. Cesalpino effected an artificial classification of plants according to their organs of reproduction, therein antedating Linnaeus. Pioneer spirits explored the Orient and the Mediterranean lands for new flora. Gonzalvo Hernandez Oviedo y Valdez (1478–1547), viceroy of Mexico, and Nicholas Monardes, of Seville, furnished the earliest accounts of the medicinal plants of the New World. To the latter belongs the priority for the description of coca (1569). Travellers in all new countries were awake to the importance of the discovery of plants with medicinal properties. Thus in the succeeding century cinchona and ipecac were introduced into Europe. The Countess of Chinchon suffered from malarial fever in Lima, Peru (1630), and her prompt response to the native bark led the Jesuit priests to take it to Europe in 1632. Professional jealousy and religious differences retarded the spread of this specific for some years. Ipecac was brought from Brazil to Europe by the Portuguese friars early in the seventeenth century. Indeed, wherever the flora of a new country was investigated by these pioneers, the probable medicinal value was uppermost in their minds.

To this group of worthy benefactors of mankind belonged John Bartram. Hector St. John de Crevecoeur, a romancer of the Colonial period in Philadelphia, has attached the following pretty circumstance to the entrance of that matter-of-fact Quaker into botanical study:

> One day I was very busy in holding my plough (for thou seest that I am but a ploughman), and being weary I ran under a tree to repose myself. I cast my eyes on a daisy; I plucked it mechanically and viewed it with more curiosity than common country farmers are wont to do, and observed therein very many distinct parts, some perpendicular, some horizontal. "What a shame," said my mind, "that thee shouldst have employed thy mind so many years in tilling the earth and destroying so many flowers and plants without being acquainted with their structures and their uses." I thought about it continually, at supper, in bed and wherever I went.

An inquiry into the validity of this legend reveals that John Bartram had written to Alexander Catcot, in 1742, of his inclination to botany and natural history from the age of twelve years. His son, William, remarked that "he had a very early inclination to the study of physic and surgery. He even acquired so much knowledge in the practice of the latter science, as to be very useful: and, in many instances, he gave great relief to his poor neighbors, who were unable to apply for medicines and assistance to the physicians of the city. It is extremely probable that, as most of his medicines were derived from the vegetable kingdom, this circum-

stance might point out to him the necessity of, and excite a desire for, the study of botany.''

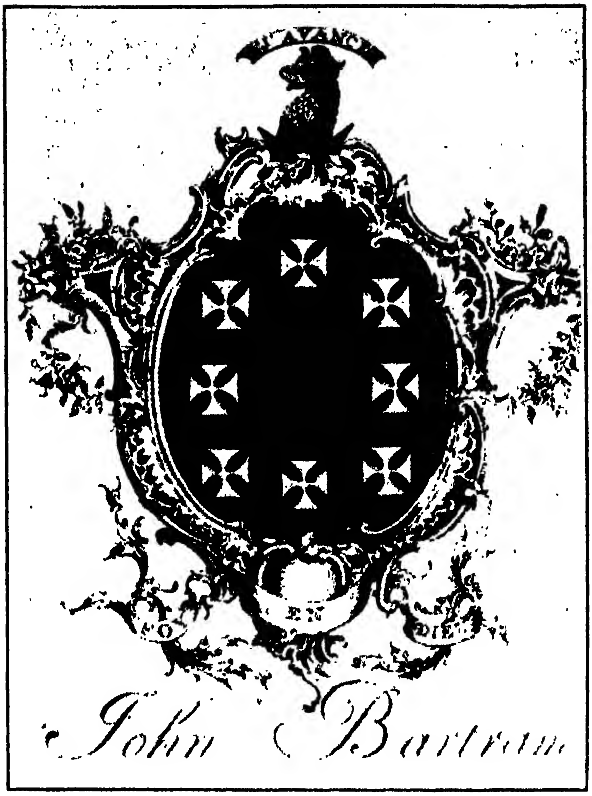
The evidence is clear, therefore, that John Bartram entered the serious study of botany from his primary interest in physic. His attitude is best translated in Emerson's words:

> If I knew
> Only the herbs and simples of the wood,
> Rue, cinquefoil, gill, vervain and agrimony,
> Blue-vetch and trillium, hawkseed, sassafras,
> Milkweeds and murky brakes, quaint pipes and sundew,
> And rare and virtuous roots, which in these woods
> Draw untold juices from the common earth,
> Untold, unknown, and I could surely spell
> Their fragrance, and their chemistry apply
> By sweet affinities to human flesh.
> Driving the foe and establishing the friends,—
> O, that were much, and I could be a part
> Of the round day, related to the sun
> And planted world, and full executor
> Of their imperfect functions.

John Bartram never completed the study of medicine as Haller and others have erroneously stated.

Having resolved to pursue the study of botany, Bartram faced almost insuperable obstacles in the accomplishment of his end. His level-headed wife attempted to dissuade him on the grounds of the detracting influence of such an avocation from the work of the farm. At first he was inclined to heed her advice, but finally the lure of the unknown overcame the force of her objections and Bartram sought the counsel of a bookseller in Philadelphia. The common botanical texts were in Latin; so he procured a Latin grammar together with a text on botany. Obviously, a native-born American of Quaker farmer parents was afforded very meager educational advantages in the Colonial period. However, with the assistance of a neighboring schoolmaster and by dint of close application he obtained a working knowledge of the classical language and of the rudiments of botany. His fundamental deficiencies were never entirely effaced; but his energy and assiduity in collecting and describing the wonders of the plant life of America led Linnaeus to term him ''the greatest natural botanist of the age.''

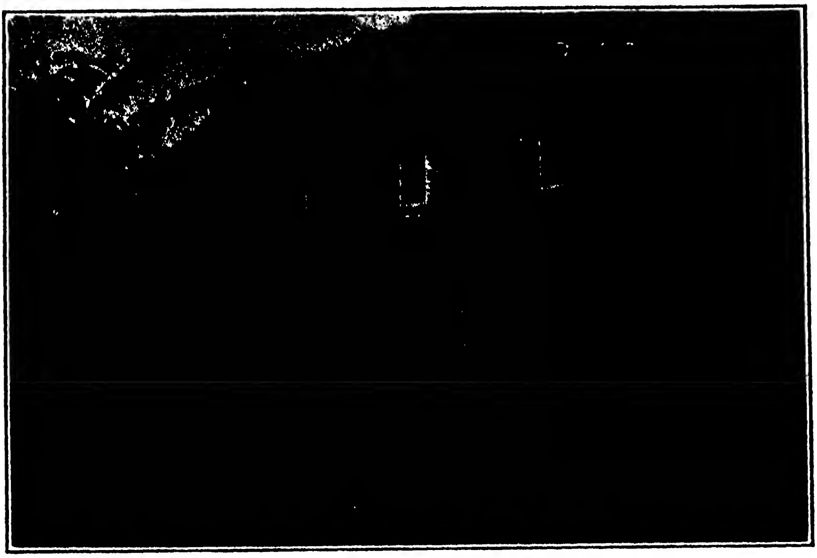
The scope of Bartram's influence and the extent of his observations were greatly enhanced by the fortunate enlistment of the interest of Peter Collinson, of London, through the mutual services of James Logan and Joseph Breintnall. Collinson, a wool-draper by occupation, was one of the most distinguished patrons of natural science in the English-speaking world of the eighteenth century.



The Bartram Coat of Arms

Through his wide acquaintanceship, scientific and financial recognition came to the obscure Bartram toiling in the wilds of a new continent. The fascinating correspondence between the two kindred spirits was preserved to posterity by the unusual custom of Bartram in retaining a rough copy of all his letters together with all received messages. To him this contact with Collinson and other students of botany in this country and abroad must have been the very breath of life, and we can picture him reading and re-reading the letters of Linnaeus, Gronovius, Catesby, Sloane, Fothergill, Colden, Garden and Franklin by the uncertain candle light after his labors of the day were ended. Many of these original letters are preserved by the Historical Society of Pennsylvania, but unfortunately the Linnaean manuscripts are missing. To William Darlington due credit is given for the difficult labor of love in the transcription of these letters, whereby they have been rendered more generally useful.

The interesting correspondence between Collinson and Bartram continued, without visits between the principals, for some thirty-



BARTRAM HOMESTEAD
Eastern (Front) Exposure

five years. Collinson on his part professed a most receptive attitude. "My inclination and fondness to natural productions of all kinds is agreeable to the old proverb: Like the parson's barn,—refuses nothing." Every letter from England brought renewed requests for seeds or plants or expressions of gratitude for past favors. For example, on January 20, 1734, Peter Collinson wrote:

> Please to remember those Solomon's Seals, that escaped thee last year. The great and small Hellebore are great rarities here, so pray send a root or two of each next year. Please to remember all your sorts of lilies; and your spotted Martagons will be acceptable.
>
> The Devil's Bit, or Blazing Star, pray add a root or two, and any of the Lady's Slippers.

In this particular letter are included directions for the packing of botanical materials, for in the long transit of two to three months losses through the inroads of rodents and other vermin were most disheartening. "A great many may be put in a box 20 inches or 2 feet square, and 15 or 16 inches high;—and a foot in earth. This may be put under the captain's bed, or set in the cabin, if it is sent in October or November. Nail a few small narrow laths across it, to keep the cats from scratching it." Another passage suggests the use of tobacco leaves to protect letters from insects.

Nor were Collinson's requests limited to the vegetable kingdom. At times it was a plea for birds, again for birds' nests. Moths

were sought on another occasion. Turtles were always interesting to this omnivorous student of nature. A characteristic passage reads:

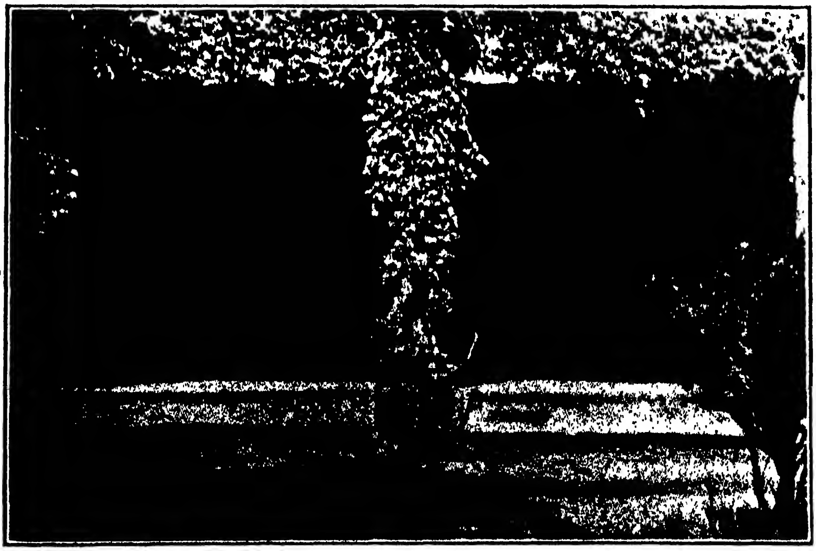
> If any Land or Water Terrapins happen in thy way, save them and send them; but not the great Mud Turtle. I only want his shell; and if Billy would paint his curious figure, it would be better. If any Orchis, Calceolus Maria, Martagons, Lilies, or any other curious plant—think on thy old friend, P. Collinson.

The following attests his diversified interest:

> In the course of thy travels, or in digging the earth, or in thy quarries, possibly some sort of figured stones may be found, mixed or compounded with earth, sand, or stone and chalk. What use the learned make of them is that they are evidences of the Deluge.

In return for Bartram's contributions Collinson at first made numerous gifts of a personal nature. For instance in January, 1735, he wrote:

> I am very sensible of the great pains, and many tiresome steps, to collect so many rare plants scattered at a distance. I shall not forget it; but in some measure to show my gratitude, though not in proportion to thy trouble, I have sent thee a small token: a calico gown for thy wife, and some odd little things that may be of use amongst the children and family.



Bartram Homestead
Eastern (Front) Entrance

ENTRANCE—EAST

John Bartram thus expressed his gratitude for favors received from Peter Collinson, December 10, 1745:

Now, though oracles be ceased, and thee hath not the spirit of divination,—yet, according to our friend, Doctor Witt, we friends that love one another sincerely, may, by an extraordinary spirit of sympathy, not only know each other's desires, but may have a spiritual conversation at great distances one from another. Now, if this be truly so,—if I love thee sincerely—and thy love and friendship be so to me—thee must have a spiritual feeling and sense of what particular sorts of things will give satisfaction; and doth not thy actions make it manifest? For, what I send to thee for, thee hath chosen of just such sorts and colours as I wanted. Nay, as my wife and I are one, so she is initiated into this spiritual union; for thee has sent her a piece of calico so directly to her mind, that she saith that if she had been there herself, she could not have pleased her fancy better.

A most happy acknowledgment from a period when the affairs of men ran less tumultuously than to-day and men found time to voice their sincere appreciation!

However, the tide of correspondence between these two Quaker botanists did not run smoothly at all times. The frugal Collinson at one time thus resented the disposition of certain wearing apparel sent to Bartram:

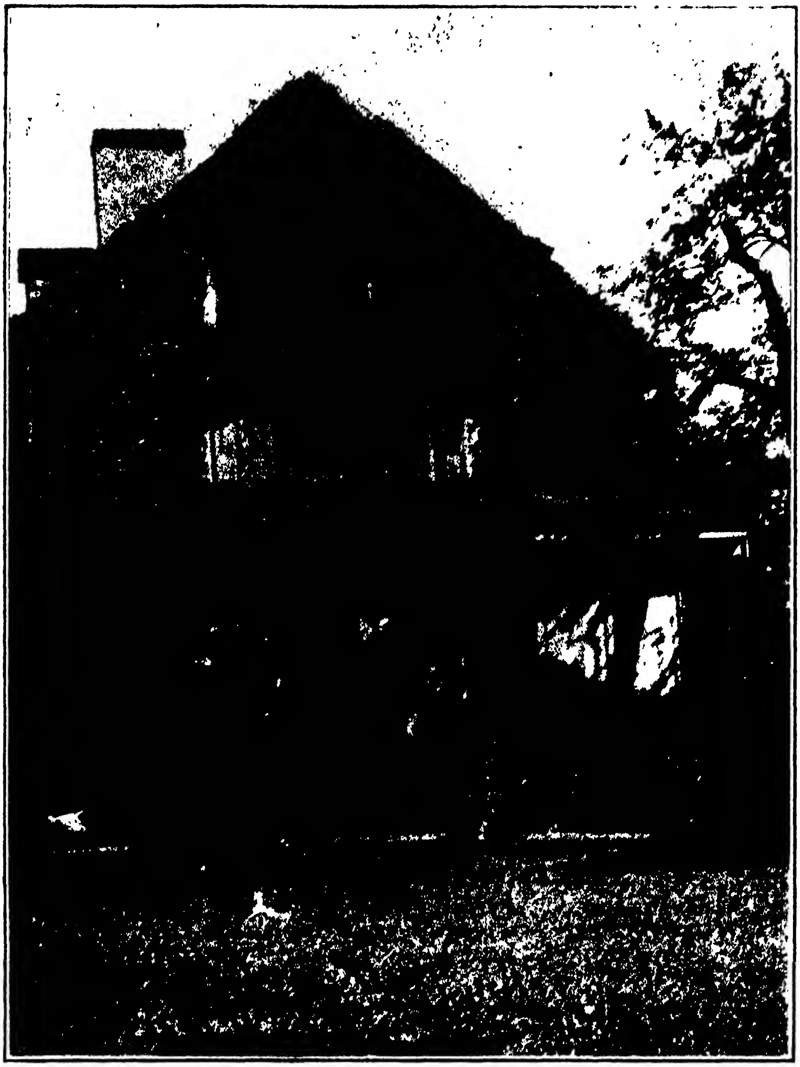
One thing I forgot to mention before, and what very much surprised me, to find thee, who art a philosopher, prouder than I am. My cap, it is true, had a small hole or two on the border but the lining was new. Instead of giving

it away, I wish thee had sent it me back again. It would have served me two or three years, to have worn in the country, in rainy weather.

Of Collinson's disinterested services to the Pennsylvanian there can be no doubt. He personally enlisted the financial support of several wealthy British commoners and noblemen in Bartram's work. Chief among these were Philip Miller, Lord Petre and the Duke of Richmond. Their first commission consisted in the request for an accurate mapping of the Schuylkill River, a task which Bartram discharged to their complete satisfaction. But their primary interest was in the enrichment of their gardens by the importation of strange plant life from America. By this medium Bartram was responsible for the introduction into England of the bush honeysuckle, fiery lilies, mountain laurel, dog-tooth violet, wild asters, gentian, ginseng, sweet ferns, magnolia, tulip, locust trees, hornbeam, witch-hazel, spruce, hemlock, red and white cedar and sugar maple. This is by no means a complete list nor was the current entirely eastward; for his English friends were at the same time enriching the flora of his garden by their contributions. To him came lilacs, tulips, narcissus, roses, lilies, crocuses, gladioli, iris, snapdragons, cyclamens, poppies and carnations, in addition to many species of fruit and shade trees. The charming introduction of one exotic tree to our shores by Collinson invites preservation:

Don't use the Pomegranate inhospitably, a stranger that has come so far to pay his respects to thee. Don't turn him adrift in the wide world: but plant it against the south side of thy house, nail it close to the wall. Dr. Fothergill says, of all trees this is the most salutiferous to mankind.

Peter Collinson was not unmindful of the demands patronage might impose. Hence: "Friend John, this is only a hint, by the way: Lord Petre is a great admirer of your foreign wild waterfowl. If at any time an opportunity offers, send him some. Thou will lose nothing by it." Peter evidently felt that it behooved him to act as social proctor to the farmer John. For example, after James Logan had ordered Parkinson's Herbal for Bartram, Collinson wrote (April 28, 1736), "It may look grateful, every now and then, to call and inquire after thy good friend Logan's welfare." He furthermore deemed it advisable to urge Bartram to appear in his best clothes in visiting the Virginians. In 1765 Collinson was instrumental in the appointment of his American friend as botanist to the king at the munificent salary of fifty pounds a year. Two years later he wrote to Bartram thus: "I am glad thou hast sent some plants and seeds to our gracious King, as thy annuity is regularly paid. I dare say any of thy Journals would be



SOUTH END OF BARTRAM HOMESTEAD

very acceptable to him; could they be copied fair? Send him every year one; for he must not be cloyed by too much at once. Begin with the first after thou received the salary. This would keep thee in his memory."

Freed in a measure from the duties on his farm by the aforementioned support, at first from private sources in England and later from the king, Bartram extended his field of botanical collection and study to New Jersey, Delaware, the Catskills and Southern New York, Maryland and Virginia and more latterly to

Georgia, Florida and the western portion of the Carolinas. He explored his native state from the Delaware to the Ohio and throughout its breadth. From its mountains went the beautiful rhododendron, "glorious beyond expression" in Collinson's opinion when it blossomed in his garden. Bartram laconically outlined his trip to Virginia as follows:

I have performed my journey through Maryland and Virginia, as far as Williamsburgh so up James River to the mountains, in many very crooked turnings and windings, in which, according to the nearest computation I can make, betwixt my setting out and returning home, I travelled 1100 miles in five weeks' time; having rested but one day in all that time; and that was at Williamsburgh.

More remarkable, however, was his trip to Florida in his sixty-sixth year to explore and map the St. John's River and to report on the colonization possibilities of the land. The journal of this period is extant but lacks the vital interest of his journal dealing with the earlier trip to the Five Nations in the company of Conrad Weiser, the commissioner from Virginia, who arranged a treaty with these tribes. In the former the impression gathers to the reader that John Bartram was the unwitting tool of devising agents whose sole interest in his observations lay in his approbation of their lands. Indeed Bartram's rather stilted account of the flora and soil forms a small appendix to William Short's descriptive brochure on Florida. For this position Bartram paid dearly in the subsequent location and dismal failure of his favorite son Billy at indigo farming on the St. John's. "Observations on the inhabitants, climate, soil, rivers, productions, animals, and other matters worthy of notice made by Mr. John Bartram, in his travels from Pensilvania to Onondago, Oswego and Lake Ontario in Canada" embody his earlier journal and contain some interesting commentaries on the subjects mentioned. The Indian customs particularly invited his attention and he wisely remarked, "Their morals are little if at all mended by their frequent intercourse with us Christians, tho I am persuaded it is not the fault of our religion but its professors."

His travels, aside from the physical effort entailed, were not unattended by grave bodily risks. On one occasion he recorded the following:

I sent Gordon a fine parcel of Holly berries, the getting of which had like to broke my bones. I was on the top of the tree, when the top that I had hold of and the branch I stood on, broke—and I fell to the ground. My little son, Benjamin, was not able to help me up; my pain was grievous; afterwards very sick; then in a wet sweat, in a dark thicket, no house near, and a very cold sharp wind, and above twenty miles to ride home, thee may judge what a poor circumstance I was in; and my arm is yet so weak that sometimes I can

THE STONE DETAIL OF THE WINDOW CASEMENT AND THE DISTICH

hardly pull off my clothes. [But mark the indomitable courage!] Yet I have a great mind to go next fall to Pittsburgh, in hopes to find some curious plants there.

Fever, jaundice and dysentery were his lot on his Florida expedition. Venomous reptiles and not less venomous savages beset his innocent path. One encounter with an Indian was especially disturbing. He wrote: "Many years past, in our most peaceable times, far beyond our mountains, as I was walking in a path with an Indian guide, hired for two dollars, an Indian man met me and pulled off my hat in a great passion, and chawed it all around—I suppose to show me that they would eat me if I came in that country again." However, Bartram's personal reaction to such hostile manifestations was translated in these words, "I hope to set out to search myself, if the barbarous Indians don't murder me (and if I die a martyr to Botany, God's will be done;—His will be done in all things)."

It must not be inferred from this statement that John Bartram with his Quaker upbringing and profession of faith was a supine pacifist. Roundly scoring his friend Peter Collinson, who had philosophically discoursed upon the subject of Indian relations in the *Gentleman's Magazine*, Bartram wrote:

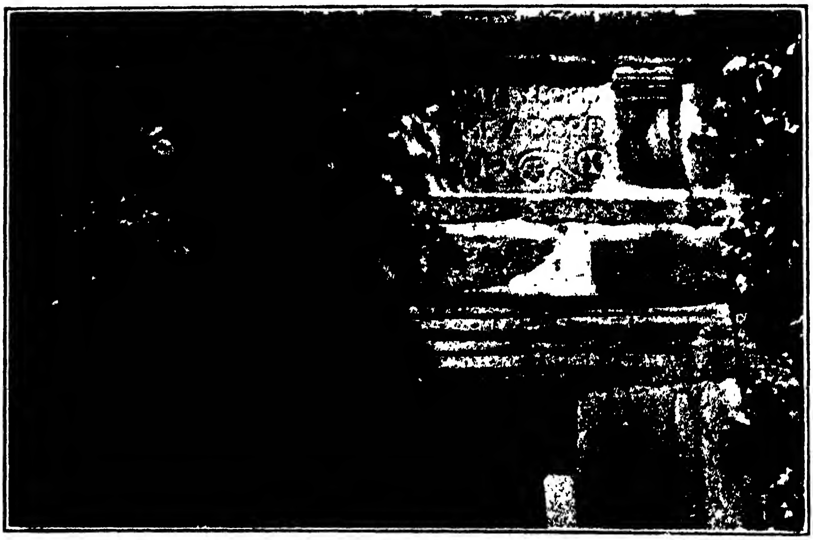
> The most probable and only method to establish a lasting peace with the barbarous Indians is to bang them soundly, and to make them sensible that we are men whom they for many years despised as women. Until then, it is only throwing away men, blood and treasure, to make peace with them. Perhaps now, and only now, is the critical time offered to Britain to secure not only her old possessions, but her so much boasted new acquisition, by sending us sufficient supplies to repel effectually those barbarous savages.

On another occasion he expressed the following sentiment to Benjamin Franklin:

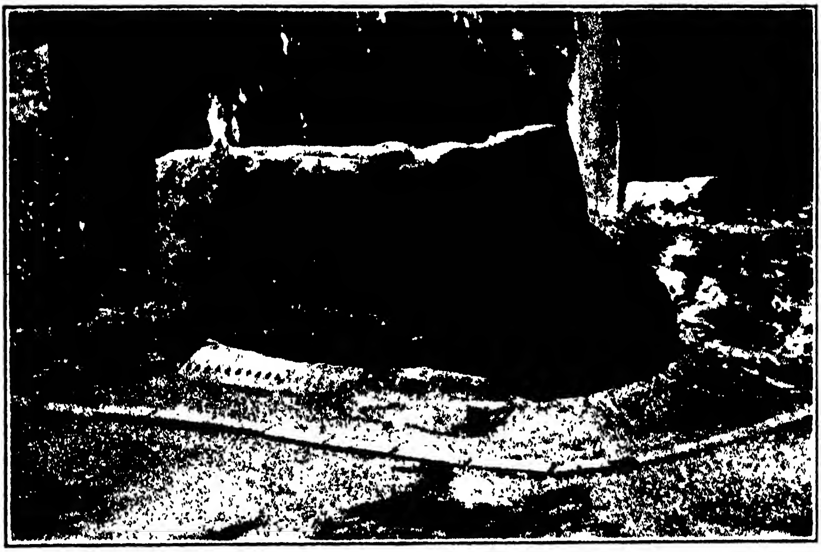
> Thy poor, yet honest Bartram is daily in mourning for the calamities of our province. Vast sums spent, and nothing done to the advantage of the King or country. How should I leap for joy, to see or hear that the British officers would prove by the actions, the zeal and duty to their prince and nation, they so much pretend in words.

John Bartram entertained the current distrust of the French and to them attributed the hostility of the Indians. "O Pennsylvania! thou that was the most flourishing and peaceable province in North America, art now scourged by the most barbarous creatures in the universe. All ages, sexes and stations have no mercy extended," he lamented.

Bartram and Collinson on occasions engaged in amusing raillery at expense of one another. A strong partisan of William Pitt,



THE RELIGIOUS DISTICH



WATER TROUGH

Bartram was the recipient of this thrust from his friend Collinson (1763). "Glorious Pitt so presides in my dear John's mind, he is insensible to complaints, except on the sorry peace that hath given so great an empire to Britain!" To which Bartram retorted, "But the Indians instigated by the French, will not let us look at so much as a plant, or tree, in this great British empire." Peter did not relent. "What a glorious scene is opened in that rich country about Pensacola– if that despised country is worthy thy visitation. But because Pitt did not get it, thou canst not venture there on any pretence! All beyond the Carolinas is forbidden ground. They are none of thy darling Pitt's acquisition."

The advantage was not always to the Englishman. On one occasion he saw fit to chide Bartram for his extravagance in purchasing botanical works, quoting from a biblical source Solomon's admonition that "in the reading of books there is no end." Whereupon John replied, "I take thy advice about books very kindly,—although I love reading such dearly: and I believe, if Solomon had loved women less, and books more, he would have been a wiser and happier man than he was."

Throughout the interchange of correspondence and botanical specimens between Bartram on one hand and his British and Continental friends on the other, there was the constant inquiry into the medicinal value of the different plants. At various times Collinson inquired for "the root of the Aristolochia, which is of such sovereign remedy for sore breasts," "a root of the grassy leaves, that bear pretty little blue flowers,—that's good against obstruc-

tions of the bowels'' and the papaw reputed to possess remarkable medicinal virtues. As has been previously noted John Bartram was responsible for the introduction of ginseng into England, and the shrewd Collinson, realizing the economic possibilities of exporting the same to the Orient, wrote:

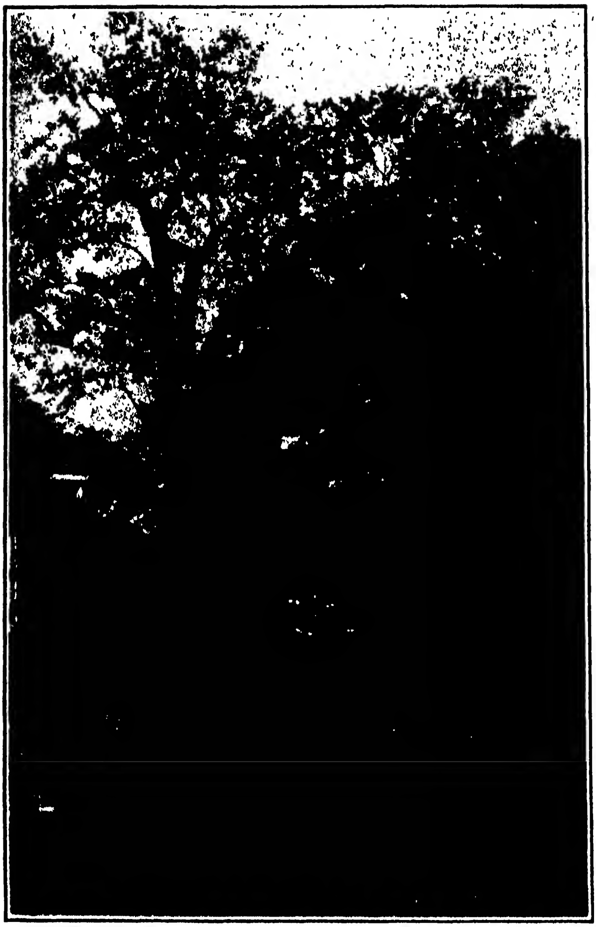
> I sent some Ginseng roots to China. If they sell well a good, profitable trade may be carried on. In the meantime, sow the seed, and raise a stock to furnish my friend, when he returns. I intend the benefit for thyself. Keep that a secret, and raise what thee canst for I have an opinion it will turn to account if my friend manages it rightly.

If the authority of Wood and Bache be admitted, the earliest shipments of the roots from this country to Canton were worth their weight in gold. The Chinese have for centuries credited ginseng with unusual virtue in the control of impotency; and it is to be hoped that Bartram shared in the profits of the exploitation of this root, even though no therapeutic properties have ever been proven for it.

John Bartram wrote to Dr. John Fothergill, whose support Collinson had enlisted:

> We have abundance of medicinal roots, herbs and barks used with success amongst the common people, which are extolled for wonderful specifics, in many infirmities, upon the first discovery made by the Indians on most of them. But when our people take them, not considering age, constitution, season, nor the particular progress, or crises, of the distemper, but expect an immediate cure upon the first or second dose, they are sometimes disappointed. Then it is directly discarded and thrown out of use (especially if the patient grows worse after taking it), and another famous specific gains applause for awhile, then is subject to the other's fate, and another taken into favour.

Cider Press



LADY PETRE PEAR

Unquestionably this pharmacologic practise would find approval at the hands of antivivisectionists to-day. Several of Bartram's letters to Dr. Fothergill discussed the properties of natural mineral waters, in which subject the doctor was deeply interested.

Although not a physician, at the instance of Benjamin Franklin, Bartram wrote an appendix of American medicinal plants to Thomas Short's "Medicina Britannica." Published in 1751 by Franklin and Hall, this unusual treatise to-day possesses only historical interest. Some of Bartram's observations on the therapeutic indications for the use of certain herbs should be preserved. Spikenard was used as a poultice to fresh wounds or the roots were chewed for the relief of pain in the loins. Collinsonia (horseweed) was recommended for after-pains. Sanguinaria possessed virtue in the treatment of jaundice. Goldenrod in the form of a

decoction was advocated in rattle-snake bites. Gentian was said to be "used with good success for the pleurisy, and in New England, for a vomit. It is a powerful Worker, a little churlish, yet may be a noble Medicine in skilful Hands." Blazing star was characterized as "a great Resister of fermenting Poisons, and the grievous Pains of Bowels, taken in Powder, or the Root bruised and steeped in rum, of which take a Spoonful at once, and as often as need requires, until the Pains remit." Apocinum has been continued until recent years as an emetic or cathartic. Of this drug Bartram remarked that "Peter Kalm saith it is excellent for the hysteric Passion." Boneset tea was granted virtue as an emetic in intermittent fever.

For lobelia or the puke weed Bartram made such remarkable claims that the passage is quoted verbatim:

The learned Peter Kalm (who gained the Knowledge of it from Colonel Johnson, who learned it of the Indians, who after great Rewards bestowed on several of them, revealed the Secret to him) saith, That the Roots of this Plant cureth the Pox much more perfectly and easily than any mercurial Preparations, and is generally used by the Canada Indians for the Cure of themselves, and the French that trade amongst them, tho' deeply infected with it. They take a Handful of the Roots, and boil them in a Quart of Water, and drink the Decoction, beginning with Half a Pint at first, if the Patient be weak, then increase the Dose every Day as he can bear its purging; but if he can't bear it every Day, let him omit it a Day or two, then take to it again, as he finds Occasion, until he is cured: They wash the Ulcer with the Decoction; but if it be deep and rotten, they put some Powder of the inner Bark of the Spruce-tree into it, which helps to dry it up; but if

THE LOWER REACHES OF THE SCHUYLKILL

the Disease is inveterate, they drink the Decoction of Ranunculus Folio Reniformus. An old Sachem told Colonel Johnson of another Shrub, with a red root, from which proceeds several slender branches, eighteen Inches or two Feet long, on which grow Spikes of white Flowers which produce three square black Seed-Pods; the Leaves some of our People drink as Tea, and some smoak it with Tobacco; the Roots of this bruised and boiled, and the Decoction drank, the Sachem said, he preferred to the Lobelia; but the Lobelia seems to be of the most general use, and with extraordinary Success. [Bartram continues,] More particular Directions how to use the Lobelia-Root for the Venereal Disorder, obtained from the Indians, by Colonel Johnson.

After making a Decoction of it, the Patient is to drink about two Gills of it very early in the morning, fasting, the same before dinner, and Bedtime. Add or diminish as you find it agree with the Patient's constitution: the Third Day begin Bathing, and continue it twice a day, until the Sores are well cleansed, and partly healed, then use the Lotion but once a Day till quite well; observing all the Time to use a slender Diet (vegetable Food and small Drink) as in other Courses of Physick, a Salivation excepted. These are the Directions I have had from the Person who gave me the secret.

The crafty hand of Franklin is evident in the lengthy dissertation of this subject and especially in the heading of Bartram's appendix, "Containing Descriptions, Virtues and Uses of Sundry Plants of these Northern Parts of America; and particularly of the newly discovered Indian Cure for the Venereal Disease." Wood and Bache in discussing the use of *Lobelia syphilitica* by the Indians for the treatment of lues dismiss the matter with an opinion that its diuretic action may have influenced the course of gonorrhea. However, no such construction can be placed on Bartram's statement of the healing of ulcers under its administration and local use.

Were John Bartram's scientific position to rest on his medical contributions alone, his title to fame would be rather insecure. His botanical observations were not entirely morphologic, as the following letter bears witness:

I have this spring made several microscopical observations upon the male and female parts in vegetables, to oblige some ingenious botanists in Leyden, who requested that favour of me, which I hope I have performed to their satisfaction, and as a mechanical demonstration of the certainty of this hypothesis, of the different sex, in all plants that have come under my notice. I have made several successful experiments, of joining several species of the same genus, whereby I have obtained curious mixed colours in flowers, never known before; but this requires an accurate observation and judgment to know the precise time.

Benjamin Rush suggested to Bartram the existence of nerves in plants. The latter immediately subscribed to the theory advancing the apparent purposeful movements and adaptations of plants as evidences of intelligence.

Of bird migration Bartram remarked, "For all these wild creatures, of one species, generally seem of one community; and rather than quarrel, will move still a farther distance, where there is more plenty of food—like Abraham and Lot; but most of our domestic animals are more like their masters; every one contends for his own dunghill, and is for driving all off that come to encroach upon them." His position in such matters was invariably substantial. In disagreeing with another observer regarding the characteristics of turtles, he said, "But as for their barking, I believe thy relator barked, instead of the turtle."

Geology was ever a realm of fascinating speculation to him. He once wrote his friend Peter: "My dear worthy friend, thee can't bang me out of the notion that limestone and marble were originally mud, impregnated by a marine salt, which I take to be the original of all our terrestrial salts." Over a century before the famous *Challenger* Expedition, Bartram suggested to John Frederic Gronovius the feasibility of detailed soundings of the seas.

> Query, whether these vast chains of mountains, if these be such, may not be, in part, the cause of the currents in the sea, which our navigators complain so much of; and is it not probable, that there may be various kinds of fish in the great vales, between these ridges, which never appeared, nor can live, near the surface of the water?

The modern geologic survey finds an accurate forecast in a letter of Bartram to Dr. Alexander Garden, of Charleston, South Carolina (March 14, 1756), wherein he proposed to

> bore the ground to great depths, in all the different soils in the several provinces, with an instrument fit for the purpose, about four inches in diameter. The benefit which I shall propose from these trials, is to search for marls, or rich earths, to manure the surface of the poor ground withal. Secondly, to search for all kinds of medicinal earths, sulphurs, bitumens, coal, peat, salts, vitriols, marcasites, flints, as well as metals. Thirdly, to find the various kinds of springs, to know whether they are potable, medicinal, or mechanical. By this method we may compose a curious subterranean map.

Peter Collinson presented certain of Bartram's observations before the Royal Society, which highly commended his efforts. One philosophic communication advancing a theory of the balance between the vegetable and the animal kingdoms won their especial approbation. Collinson set Bartram's mind at rest in the matter of his literary style, by remarking that there was no apology necessary "for thy natural way of expressing thyself is more acceptable, clear and intelligible than a fine set of words and phrases." At times he did criticize John's brevity, feeling that much of the substance of the communication was thereby lost. On the other

hand, Bartram on occasions displayed an excellent command of English and an almost poetic finish in description. His Quaker inhibition was doubtless lifted when the following letter to Dr. Garden was inscribed:

> What charming colours appear in the various tribes, in the regular successions of the vernal and autumnal flowers– these so nobly bold—those so delicately languid! What a glow is enkindled in some, what a gloss shines in others! With what a masterly skill is everyone of the varying tints disposed! Here, they seem to be thrown on with an easy dash of security and freedom; there, they are adjusted by the nicest touches. The verdure of the empalement, or the shadings of the petals, impart new liveliness to the whole, whether they are blended or arranged. Some are intersected with elegant stripes, or studded with radiant spots; others affect to be genteelly powdered, or neatly fringed; others are plain in their aspect, and please with their naked simplicity. Some are arranged in purple; some charm with the virgin's white; others are dashed with crimson; while others are robed in scarlet. Some glitter like silver lace; others shine as if embroidered with gold. Some rise with curious cups, or pendulous bells; some are disposed in spreading umbels; others crowd in spiked clusters; some are dispersed on spreading branches of lofty trees, on dangling catkins; others sit contented on the humble shrub; some seated high on the twining vine, and wafted to and fro; others garnish the prostrate, creeping plant. All these have their particular excellencies; some for the beauty of their flowers; others their sweet scent; many the elegance of foliage, or the goodness of their fruit: some the nourishment that their roots afford us; others please the fancy with their regular growth: some are admired for their odd appearance, and many that offend the taste, smell and sight, too, are of virtue in physic.

Bartram for his part entertained no illusions as to his own shortcomings. "I am glad my friend Dr. Fothergill hath perusal of my notion of the antediluvian impression of marine shells, in our mountain rocks, or any of my rambling observations. I hope, if I can stand the test with his trial, I shall come out like gold well purified. I had rather undergo now a thorough purging—a long fusion, than to have any dross left behind." Contemporary opinion was almost unanimous in acclaiming John Bartram's ability as a botanist. Fothergill spoke of his indefatigable labors and amazing success. The accuracy of his observations was the subject of frequent comment. James Logan, who early stimulated Bartram by word and gifts of botanical texts, remarked that he was "worthier of a heavier purse than fortune had yet allowed him, and had a genius perfectly well turned for botany." Colden spoke of his industry and genius. Dr. John Hope, professor of botany in Edinburgh, wrote "The great reputation which you have just acquired, by many faithful and accurate observations and that most extraordinary thirst of knowledge which has distinguished you, makes me extremely desirous of your correspondence."

A single discordant note is discerned in the attitude of Dr. Alexander Garden. In this instance it is difficult to reconcile Garden's duplicity on the grounds of jealousy; for while his personal communications to Bartram were most cordial, he openly accused him, in a letter to Linnaeus, of misappropriating certain botanical specimens without giving him proper credit. The incident ran thus:

> You tell me you are surprised that I overlooked a new species of the live oak which John Bartram found near Charleston. Let me assure you that John Bartram received from me these very specimens, some of the Phillyrea and many others, from my Hortus Siccus, of which he has, it seems, made a different use from what I apprehended.

Garden on another occasion wrote to John Ellis that Bartram

> knows nothing of the generic character of plants, and can neither class them nor describe them; but I see that, from great natural strength of mind and long practice, he has much acquaintance with specific characters; though this knowledge is rude, inaccurate, indistinct and confused, seldom determining well between species and varieties . . . He tells me that he is appointed King's Botanist in America. Is it really so? Surely John is a worthy man; but yet to give the title of King's Botanist to a man who can scarcely spell, much less make out the characters of any one genus of plants, appears rather hyperbolical. Pray how is this matter? Is he not rather appointed or sent, and paid, for searching out the plants of East and West Florida and for that service only to have a reward and his expenses?

This depreciatory and patronizing tone was entirely foreign to the spirit of such remarks as the following from Dr. Garden to Bartram: "Your letters particularly give me pleasure. They always contain something new and entertaining, on some new-discovered work of God." Or again, "It appears to me to be an age since I have had the pleasure of hearing from you. Pray, write me, and tell me what you are doing; for I know you can't be idle. Tell me what you are discovering; for I know your imagination and genius can't be still. How many wonders of creation do you daily see? Why won't you let me know a few?"

John Bartram's outline of his library to Sir Hans Sloane was evidence of his sincere desire to improve his mind:

> The first authors I read, were Salmon, Culpeper, and Turner. These James Logan gave me . . . Doctor Dillenius sent me Miller's Dictionary, and his own book of Mosses. Lord Petre sent me Miller's Second Part, and the second book of Turner's complete Herbal; and thee kindly obliged me with thy history of Jamaica. Our friend Peter sent me them fine books of Nature Delineated. Catesby sent me his books of Birds, and some books of Physic and Surgery, which was my chief study in my youthful years.

This library has been divided between the Historical Society of Pennsylvania and the Bartram Association through an unfortu-

nate difference of opinion as to its custodianship. The latter group has placed its Bartramana in the department of botany of the University of Pennsylvania.

Benjamin Franklin, a frequent visitor to the Bartram home and a counsellor and friend to John, sought to have the latter prepare a natural history of America. "No one besides is so capable of performing," he urged. Pressing his plea still further, Franklin wrote:

> Although it may not now be suitable for you to make such wide excursions as heretofore, you may yet be very useful to your country, and to mankind, if you sit down quietly at home, digest the knowledge you have acquired, compile and publish the many observations you have made . . . It is true, many people are fond of accounts of old buildings, monuments, etc., but there is a number, who would be much better pleased with such accounts as you could afford them; and for one I confess, that if I could find in any Italian travels, a receipt for Parmesan cheese, it would give me more satisfaction than a transcript of any inscription from any old stone whatever.

Honors from far and near sought out the self-taught botanist in his retreat along the Schuylkill. The historian notes with satisfaction that his neighbors early recognized his ability. The first draft of membership for the proposed American Philosophical Society (1744) included John Bartram's name; and when the plan finally materialized in 1768, his name was continued as the botanical representative in this organization which was through the years to contribute so effectively to the propagation of useful knowledge in America. The Swedish Society of Science conferred its diploma on Bartram. With a gesture of generosity a Society of Gentlemen founded in Edinburgh for the importation of plants and seeds sent Bartram a medal, in lieu of currency, for a shipment which had gone astray. Recognition through a botanical god-child has several times been denied Bartram by the replacement of a proposed designation. The attachment of his name to certain of the mosses is a singular trick of fate, since this field of plant life was the last to be cultivated by him. The genus Bartramia Hedwig with its several species is a common variety of soft green moss carpeting damp shady glades and protected moist niches in rocks. Their capsules, when moist, appear as tiny green apples with the single ruddy cheek marking the operculum of each. This generic characteristic gives license for the common name of apple moss.

It is not to be presumed that Bartram's devotion to botany was achieved through a neglect of his farm or the more material affairs of the world. From a paternal uncle he had inherited some land in Darby Township, Delaware County, Pennsylvania. However with the sheriff sale of the lands, goods and chattels of one Frederick Schobbenhausen in 1728, John Bartram gained possession of

five acres of land in Kingsessing Township along the Schuylkill. This tract formed the nucleus of his garden which was begun about two years later. By commendable industry John Bartram extended his fields to ultimately include about three hundred acres. The construction of retaining walls and drainage ditches reclaimed a considerable acreage of swamp land along the river, while a system of irrigation rendered another portion of soil arable under all atmospheric conditions. Bartram's fair treatment of his negro slaves enabled him to manage his farm advantageously and yet to absent himself for continued periods on botanical excursions. Following the precepts of the Quaker creed, Bartram had freed his slaves, given them a fair wage and clothing and afforded them certain educational and religious advantages. One of these negro freedmen, Harvey, acted as Bartram's steward for many years and in this capacity was a familiar figure in the streets of Philadelphia where he transacted all his master's business. Harvey was buried in the garden on a knoll overlooking the river.

With his own hands, John Bartram quarried and cut the stone with which to build a home on his river tract. He wrote Jared Eliot with all the pride of a skilled craftsman:

> I have split rocks seventeen feet long, and built four houses of hewn stone, split out of the rocks with my own hands. My method is, to bore the rock about six inches deep, having drawn a line from one end to the other, in which I bore holes about a foot asunder, more or less, according to the freeness of the rock; if it be three or four or five feet thick, ten, twelve or sixteen inches deep. The holes should be an inch and a quarter diameter, if the rock be two feet thick; but if it be five or six feet thick, the holes should be an inch and three quarters diameter. There must be provided twice as many iron wedges as holes; and one half of them must be made full as long as the hole is deep, and made round at one end, just fit to drop into the hole; the other half may be made a little longer, and thicker one way, and blunt-pointed. All the holes must have their wedges drove together, one after another, gently, that they may strain all alike. You may hear by their ringing when they strain well. Then, with the sharp end of the sledge, strike hard on the rock, in the line between every wedge, which will crack the rock; then drive the wedges again. It generally opens in a few minutes after the wedges are driven tight. Then, with an iron bar, or long levers, raise them up, and lay the two pieces flat, and bore and split them in what shape and dimensions you please. If the rock is anything free, you may split them as true, almost, as sawn timber; and by this method you may split almost any rock, for you may add what power you please, by boring the holes deeper and closer together.

Standing to-day, his home is a model of substantial Colonial construction. Its lines are quaint and comfortable but scarcely conventional. Ornamentation is not anticipated, but the severe scrolls in the stonework about the windows are an interesting departure. Two further examples of his handiwork in stonecutting are to be found in the garden, namely, the great watering trough

by the house and a cider press at the river's edge. It is probable that the house was constructed in several stages, since a stone in the south end is engraved

John : Ann : Bartram : 1731,

whereas the famous inscription above his study window reads thus:

It is God Alone, Almyty Lord,
The Holy One by Me Ador'd
John Bartram 1770.

The one-story extension on the southern exposure of the old homestead is especially interesting since it was utilized by Bartram as a conservatory.

In person, John Bartram was erect and above middle height. His face was long and its expression animated but controlled by a quiet dignity. No authentic likeness of him has come down to us. His habits were industrious and he found no occasion to lament the lagging hours. Amiable by nature and easy of approach, his family life was exemplary and the Bartram home a byword for Colonial hospitality. His compassionate nature spared even the lowliest insect. "Neither can I behold any of them, that have not done me a manifest injury, in their agonizing, mortal pains, without pity." As has been indicated, he carried his convictions into practice. So being opposed to slavery he freed his Negroes. His creed was inscribed over the door of his greenhouse:

Slave to no sect, who takes no private road,
But looks through Nature, up to Nature's God.

He taught his children to "do good, love mercy and walk humbly before God." In 1758 John Bartram was read out of the Monthly Meeting at Darby because of his liberal religious views. Many years before, he had written to Peter Collinson:

> Indeed I have little respect to apologies and disputes about the ceremonial parts of religion, which often introduce animosities, confusion, and disorders in the mind—and sometimes body too: but, dear Peter, let us worship the one Almighty Power, in sincerity of heart, with resignation to His divine will,—doing to others as we would have them do to us, if we were in their circumstances. Living in love and innocency, we may die in hope.

Whatever the immediate basis for the meeting's action, Bartram continued in attendance and before his death was reinstated in the church.

John, the son of William and Elizabeth Hunt Bartram, was born in Darby Township, Delaware County, Pennsylvania, on March 23, 1699. His grandfather, John Bartram, had emigrated to America from Ashborn, England, in 1682. The family arose from the English soil of Derbyshire; but genealogists have traced their earlier origin to a Norman gentleman who came to England

with William the Conqueror. An ancestor, spelling his name Bertram, served under William at Hastings. The family divided after establishment in England or a second individual of the same name (John Bartram believed them to have been brothers) went to Scotland soon after the landing of the Normans. In any event the name does not appear in England before the Conqueror's period, and thereafter in the various chronicles the name frequently appears in Kent, Sussex and Cumberland. The Bartram coat of arms is thus described:

Gu. on an escutheon or, betw. eight crosses pattee ar. an anvil ppr. Crest-Issuing out of an antique crown or, a ram's head ppr. Motto—j'avance.

John Bartram was twice married. His first wife was Mary Maris, of Chester Monthly Meeting, whom he married in January, 1723. Two sons were born to this union, but the mother died in 1729. Two years later John Bartram married Ann Mendenhall, of Concord Monthly Meeting, Delaware County. To this marriage nine children were born and Ann survived her husband by six years. John Bartram died on the twenty-second of September, 1777. His last illness was of short duration, but a period of profound suffering before death led him to say, "I want to die." The aged naturalist apparently feared physical incapacity more than death. He lies in an unmarked grave in the Friends' Burial Ground at Darby, Pennsylvania.

Almost his last concern on leaving this world was a fear that his cherished garden would be ravished by the victorious British, at that moment advancing from the Brandywine. The British army, as a fitting tribute to the services of the simple-minded scientist to their native land, spared the garden, which descended to the son John. However, it was William Bartram who inherited his father's love of nature and who maintained the garden in its original state. The farm was kept in the Bartram family for about a hundred years and then passed into the hands of strangers. The earliest of these, Andrew Eastwick, restored the fading glory of the garden in a measure through the efforts of his supervisor, Thomas Meehan. Financial reverses in the Eastwick affairs brought bad days for the historic old garden; and when the Pennsylvania Horticultural Society was unable to avail itself of the offer to sell at a sacrifice, the garden fell into disinterested hands and decay. Unfortunately, botanical vandals stripped it of practically all transportable plants and shrubs, until on its retrieval by the City Council through the efforts of Thomas Meehan in 1891 only a semblance of its former glory remained. Even after this transfer there was no consecutive effort to maintain the grounds in their original form. Progress in the restoration of the garden has been slow, but

the efforts of such forces as the Bartram Association are gradually making themselves felt. The Park Commission has now been given control of this historic spot and more rapid progress may be anticipated.

The present and future generations will miss the lordly cypress which from a sapling obtained in Delaware grew to be the monarch of Bartram's Garden, one hundred and seventy-five feet tall and seven feet in diameter. The Christ thorn, one of a group received from Palestine and sent by Peter Collinson to his friend John, no longer survives. The famous Bartram oak, whose anomalous leaves baffled botanists for many years, is likewise gone. The boxwood which Bartram received from the Earl of Bute still thrives. Tulip trees, buttonwoods, hornbeams and papaws planted by his hand still shade the walks. The yellow-wood is one of the finest specimens in the garden. Of the exotic trees, the ginkgo (Maiden-hair tree) from Japan is one of the most interesting. It is said to have been the first imported into this country. Horse-chestnut trees are found here, but their size would not indicate that they were the original ones which Bartram saw bloom for the first time in America in his own garden. Trumpet vines transplanted by him from the Carolinas grow luxuriantly over the old homestead and adjoining arbors.

Best known among the living ancients in the garden is the Lady Petre pear tree. In 1763, in a letter to Peter Collinson, Bartram said, "The Pear raised from her seed hath borne a number of the finest relished fruit. I think a better is not in the world." To this note Peter replied, "It has been thy patience to wait, but my pleasure to hear of the delicious pears raised from Lady Petre's seed; but she, dear good woman, is gone to rest." For over a century and a half this remarkable tree has borne fruit. Washington and Franklin enjoyed its fine pears and it continues productive. It is significant that one of John Bartram's most prized trees should have survived the storms and neglect of many generations. By this token let us seek to revive the interest in botany and particularly in the study gardens, of which Bartram's was our first and most notable example. Infinite perseverance and industry enabled a single inspired, self-educated man to establish almost two hundred years ago, in a veritable wilderness, a garden famed throughout the civilized world for its remarkable completeness in the native flora of America and for its unusual collection of exotics. Truly the improved paths and channels of communication should to-day make the restoration of this garden spot a much lighter task.

Grateful acknowledgment is made for the continued assistance of my sister, Rena S. Middleton, and Professor John W. Harshberger in the preparation of this biographic sketch.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

AN INDEX OF OLD AGE

WHY does chick or child grow rapidly at first, then gradually slow down and finally stop growing altogether? How does it know when it has got its growth?

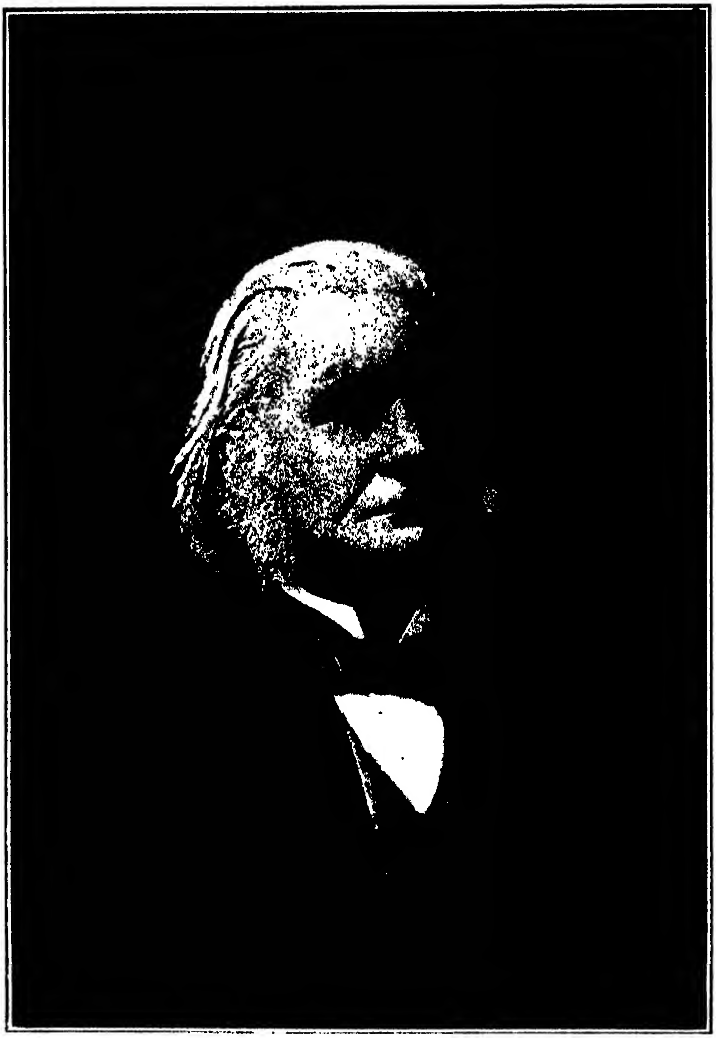
What checks the growth of a leg or a finger when it has reached the proper length? Sometimes of course it does not stop at the right time, and the unfortunate individual gets too tall to fit into a sleeping car berth, or carries through life unwieldy feet or an uncomely nose. But these exceptions only emphasize the rule.

Another mystery of like magnitude. When the individual has reached maturity, and his cells have lost their youthful zeal for expansion and settle down to a quiet life, there may arise an emergency that will set them off again. A cut or burn for instance may destroy a considerable mass of bone or muscle. The neighboring cells, quiescent for years perhaps, start to growing and multiplying at as rapid a rate as when they were young, and within a couple of days have made perceptible progress toward closing the wound. Also why is it that certain peaceful and orderly cells, without any apparent provocation, are suddenly seized with an imperialistic mania and develop a cancer?

We are so accustomed to such occurrences that we think they seem too "natural" to need explanation, yet until recently no one had been able to suggest a reason for them. But a new method of experimentation has been devised by Dr. Alexis Carrel, of the Rockefeller Institute for Medical Research, that promises to throw light upon these old questions. He has found it possible to pick out a few cells from the blood or flesh and grow them in glass flasks, where they can be experimented upon at will. If kept at the normal temperature and duly fed with blood serum and embryonic tissue juice they will thrive and multiply as well as in the body, better in fact, for they do not die of old age, but live on indefinitely. He started the artificial cultivation of a minute bit of cartilage from the heart of an unhatched chicken over twelve years ago, and it is growing yet, long after the fowl would have died if it had hatched.

Such cartilaginous tissue can not live on serum alone. Apparently its protein has to be prepared for it by certain growth-promoting agencies that he calls "trephones," that is feeders. They are produced by the white blood corpuscles and certain glandular secretions, and they decrease with age. But besides this the serum contains some sort of substance that works the other way. It restrains or prevents the multiplication of cells and so inhibits growth. The amount of this inhibiting factor in the blood increases with advancing age, rapidly at first and then more slowly.

This discovery affords a way of measuring the age of an animal by observing the effect of its blood serum on the cells under cultivation in the flasks. When, for instance, the cells were supplied with serum from a hen six weeks old they lived forty-six days. In serum from a three-



THOMAS HENRY HUXLEY

Portrait from the photograph by Mayall taken in 1893 and printed in the "Life and Letters" by Leonard Huxley, published in New York by D. Appleton, 1900. The centenary of Huxley's birth was celebrated on May 4.

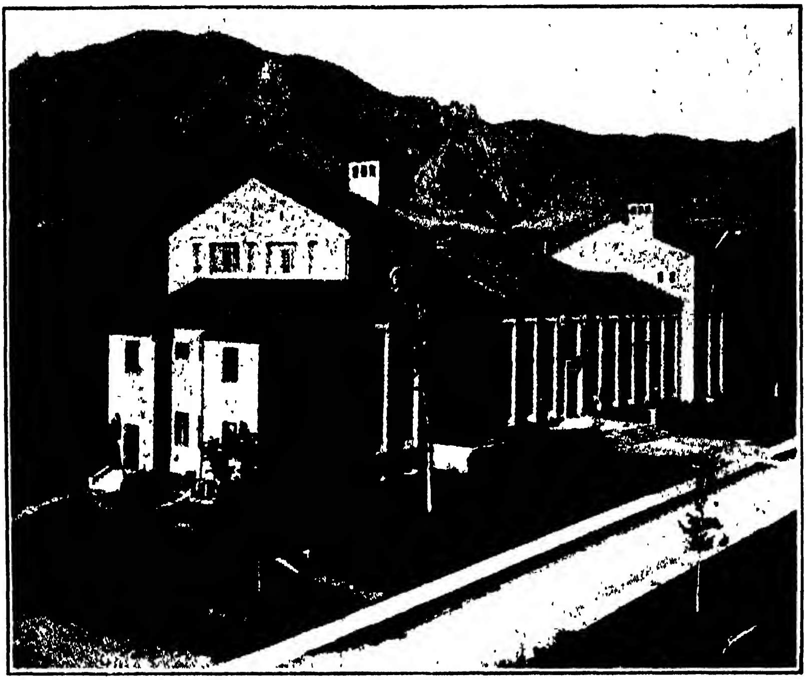
months old hen they lived thirty days. In serum from a three-year old hen they lived fifteen days, and in serum from a nine-year old hen the cells survived only four to six days. If this test could be sufficiently simplified we might be able to ascertain with accuracy the age of a spring chicken, instead of having to take the dealer's word for it.

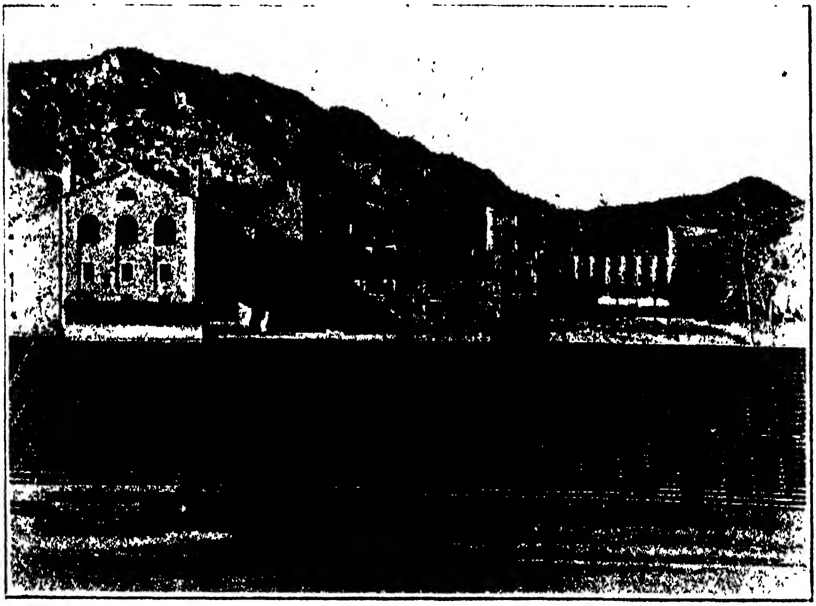
Experiments with the blood of dogs gave the same results. The serum from a dog eight years old restrained the growth of the cells ten times as much as serum from a two weeks old pup.

Whether the method can be applied to human beings remains yet to be

FROM AN AUTOGRAPH LETTER BY THOMAS H. HUXLEY

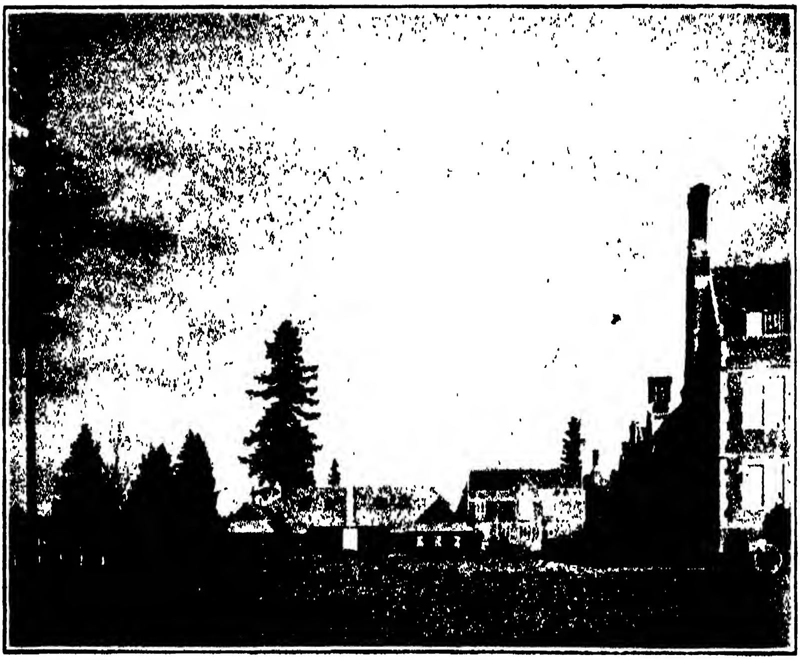
Part of a letter addressed to Sir Joseph D. Hooker on February 14, 1895, referring to the recent discovery that had been made by Dubois in Java. From the "Life and Letters."





THE UNIVERSITY OF COLORADO

Boulder, Colorado, where the Southwestern Division of the American Association for the Advancement of Science hold its annual meeting in June. Above is the arts and science building with the foothills of the Rocky Mountains in the background. Below is the new gymnasium and the Macky auditorium with the snow-covered Arapahoe peaks in the distance.



REED COLLEGE

Portland, Oregon, where the Pacific Division of the American Association for the Advancement of Science held its annual meeting in June. Above is a view of the arts building. Below are the dormitories and commons.

determined. If it can be we may be able some day to determine not only how old a person actually is, but why. And if the growth-promoting and the growth-restraining factors can be identified and independently prepared it may be possible to regulate their balance and restore it when it is disturbed.

LOOK OUT FOR "A"

We are beginning to learn our ABC's in the field of vitamins and even the groceryman can tell us which of his eatables are richest in those elusive but essential factors that the chemist has not yet been able to extract and identify.

Yet it is only twelve years since the first one was found, or to speak more accurately, found necessary. This is the one called "vitamin A" and its importance was discovered in the course of feeding experiments when it was found, contrary to what was then assumed, that all fats were not quite the same in food value, that lard was not so good as butter, and that olive oil was not so good as fish oil, and that white corn was not so good as yellow corn in promoting growth if they were the only source of fat in the nation. That is, all the fats and oils are almost equally edible and nutritious and digestible and useful in furnishing fuel to run the engines of the body, but some of them, and only some of them, have in them besides a little of something else that the body must have for growth and health.

A new series of very carefully conducted experiments by Professor H. C. Sherman, of Columbia, has shown that vitamin A is also necessary for the production of offspring. He matched twin white rats of the same litter and sex. One set was fed whole milk powder, the other skimmed milk powder. In other experiments one set was fed butter fat and the other lard or coconut fat. In other respects the rations were the same, mostly ground whole wheat. The first set therefore lived on a diet containing an ample supply of vitamin A, while the other lot had a ration that was poor in vitamin A.

The difference was striking. Both lots of the rats grew up to maturity in about the same time, but the rats that had plenty of A grew bigger and lived longer and produced more young. The rats on the low-vitamin diet weighed only 69 per cent. as much as their better fed brethren. The rats that had plenty of A lived more than twice as long as the average.

But the most striking difference was in the breeding records. The 17 females on the diets richer in vitamin A had a total of 477 young of which they raised 264. The 17 females on the diets poorer in vitamin A gave birth to only 31, and none of these lived longer than two days. Both sets had plenty of the recently discovered "fertility vitamin" X or E, since wheat germ was in both rations.

Another significant fact is that the rats on the vitamin-poor diet showed a greater "susceptibility to infection and particularly a tendency to break down with lung disease at an age corresponding to that at which pulmonary tuberculosis so often develops in young men and women."

Animals that have lived on a liberal diet will store up enough vitamin A to last a long time if they are deprived of it. Nine tenths of this is laid up in the liver. But it does not appear that any animal has the power to make this vitamin out of any foods that do not contain it. It is most abundant in cod-liver oil, butter, whole milk, liver, herring, egg yolk,

alfalfa, clover, cabbage, carrots, sweet potatoes and spinach. It is practically absent from Irish potatoes, lean meat, malt extract, wheat bran, grapes, olive oil, corn oil, lard, tallow and yeast cakes. We do not need much of A, but we need that little much.

LEGISLATIVE ORTHODOXY

In 1899 the legislature of Indiana undertook to establish a new value of Pi, that indispensable but inconvenient number which represents the ratio of the circumference of a circle to its diameter. Certainly this needs reforming as much as anything in the world. It begins 3.141592 . . . and goes like that forever; at least nobody has got to an end of the decimal, although mathematicians have worked it out to more than 700 places.

So when an Indianian ex-teacher offered to give the state the right to use free in the state schools his proof that the true value of Pi was an even 4, the legislators jumped at the chance, and a bill establishing that value was introduced and passed unanimously through three readings in the lower house and two in the upper. Of course, like politicians generally, they never thought of seeking expert advice, so Purdue and the state university were not consulted; but a member of the Indiana Academy of Sciences, C. A. Waldo, coming to see after the academy appropriation, found the lower house calling the roll on the final reading of the Pi bill. That evening he visited such senators as he could see and gave them a lesson in elementary geometry; consequently, it was defeated on its third and final reading in the senate.

If it had not been for this accidental intervention the teachers of Indiana would have had to teach a false formula to their students, and what would have happened to the trains that went around the curves laid out on this figure, and to the domes of buildings and the arches of bridges, and machinery made in the shops, so calculated, is appalling to contemplate. The Egyptians 1700 years before Christ had figured out Pi as 3.16, so that from yonder pyramids thirty-six centuries would have looked down upon Indiana. I do not know what penalty was imposed by the Indiana act upon a teacher whose students when they measured a circle got an illegal result. A statute of Oxford University in 1583 provided that any master or bachelor who deviated from the doctrine of Aristotle on any point should pay a fine of five shillings for each such offense. I do not know whether the rule has been repealed yet or not. Probably not. Oxford rarely repeals. But while it was enforced a teacher could not often afford the luxury of mentioning that the earth moves. A school prospectus of later times announces that students will be taught either that the sun moves or the earth moves, according to which parents prefer. Perhaps our private schools will soon be inserting in their application blanks; "Please specify whether you want your child taught the monkey or the Moses theory."

Heresy comes higher than it used to. Instead of five shillings a teacher in Tennessee may be fined five hundred dollars for each offense of teaching "that man has descended from a lower order of animals." At that rate, a teacher might lose his year's salary for a slip of the tongue, or for pointing inadvertently to a fossil bed, from which students might draw an illicit inference.

(Kirby in New York World)
Courtesy of the New York World

THE LITTLE RED SCHOOLHOUSE IN TENNESSEE

It is amusing to see that the newspapers in referring to the law of Tennessee and other states requiring that the reading of Scriptures in school shall be "without comment," call it "Puritanism." On the contrary, our New England ancestors insisted that the Scriptures should not be read without comment even in church. They denounced such a practice as "dumb reading," and condemned it as savoring of the ritualism from which they had revolted. The minister was required to expound the chapter passage by passage as he read, lest it should be heard unheedingly or misunderstood. When later some of the city churches began to introduce the custom of reading the Bible without explanation it was strongly opposed as a perversion of the faith. A good old orthodox Puritan living to-day would probably take his children out of a school where the Bible was read without comment, from conscientious objections.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1925

CONDITIONS IN SOUTH AFRICA FOR ASTRONOMICAL OBSERVATIONS

By Professor SOLON I. BAILEY

HARVARD UNIVERSITY

A SEARCH for an ideal site for astronomical observations has been in progress for many years. Although perfect conditions may be found nowhere on the earth, great differences undoubtedly exist. There is, especially, an increasing interest in the observation of the southern sky. Several observatories have been established in countries south of the equator, which are supported by local governments or institutions. The British government has long maintained a well-equipped observatory at Cape Town. The Harvard Observatory has carried on astronomical observations in Peru since 1889. Since 1923 the Observatory of Leiden, by special arrangement with the Union Observatory, has been extending its researches to the southern sky at Johannesburg. Also, the Yale Observatory is now establishing a branch station at Johannesburg, and the Detroit Observatory of the University of Michigan is about to erect a large telescope at Bloemfontein. Other observatories are interested in this problem. It is, therefore, of great importance to determine the most favorable southern site for astronomical observation.

The chief requisite for an astronomical station is a sky free from cloud, haze, dust and smoke. Since no locality is entirely free from clouds, it is desirable that the clouds which occur be distributed evenly throughout the year, rather than condensed into one decidedly cloudy season, such as prevails, for example, at Arequipa from December until March. There are other requirements, the chief of which, perhaps, is steadiness of the air. This is of great importance in both visual and photographic work. With marked unsteadiness a large telescope may have little or no advantage over a small one. An ideal site, also, would have freedom from strong winds, especially at night, a small diurnal range of temperature, at least a moderate altitude and accessibility, together with the necessities

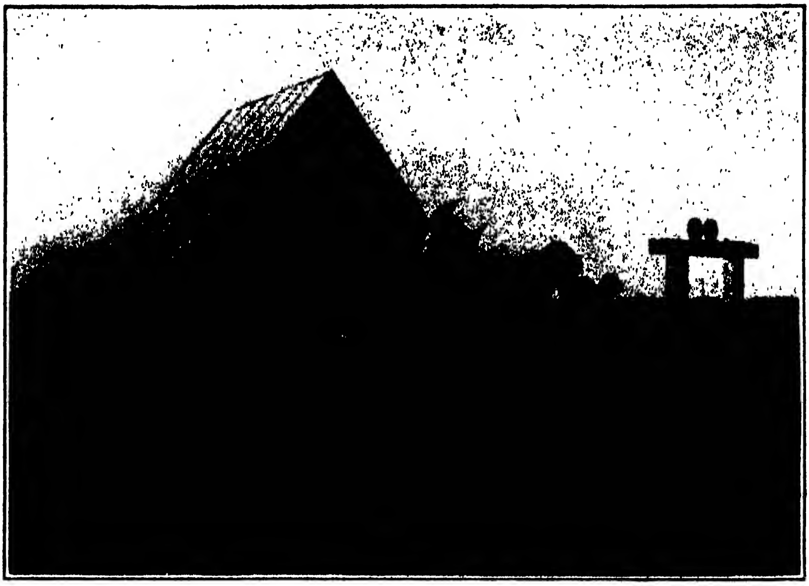
FROM THE HILL NEAR THE UNION OBSERVATORY, JOHANNESBURG

and some of the comforts of modern civilization. Also, if a branch of a northern observatory, the station should be located so far south of the equator that the entire southern sky can be studied to the best advantage.

The Harvard Observatory, in 1887, received a fund left by Uriah A. Boyden, of Boston, for the establishment of an observing station at an altitude where the atmospheric conditions would be especially favorable. It was clearly recognized that such conditions would not be found at existing observatories, which were at that time generally situated near large cities. Under the general direction of Professor Edward C. Pickering, then director of the observatory, investigations were made of various sites in the United States and along the west coast of South America. As a result of these studies, after a year of preliminary work near Lima and in Chile, the well-known branch of the observatory at Arequipa, Peru, was established, where observations have been carried on regularly until the present time.

Although Arequipa had proved to be a fairly satisfactory site, judged by the results there obtained, the amount of cloud was often large and its distribution unfortunate. It seemed worth while, therefore, to learn whether the southern hemisphere offered elsewhere a better location than Peru. The semi-arid belt of small rainfall which lies across Peru and northern Chile crosses the high plateau of South Africa. The same belt extends also over Australia, some parts of which may have extremely clear skies.

Very favorable reports had been received concerning South Africa, and it was chosen for investigation at that time. The gen-

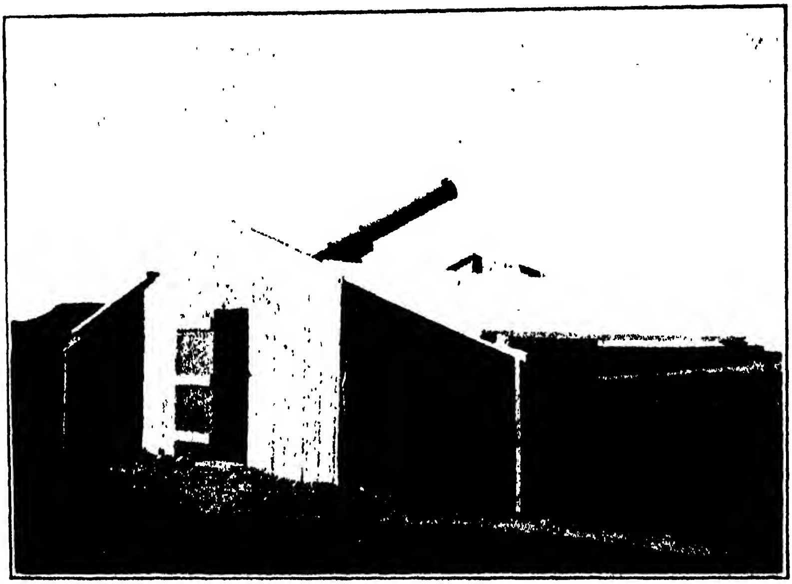


THE FRANKLIN-ADAMS TELESCOPE
Union Observatory, Johannesburg, with Dr. Innes and Mr. Wood.

eral climatic conditions of the region were fairly well known from observations carried on under the direction of the Meteorological Commission of the Cape of Good Hope and the governments of the other colonies which now make up the Union of South Africa. At many of the stations, however, cloud records were few, or entirely lacking, and no study of the steadiness and transparency of the air had anywhere been made. Under these circumstances I was asked to make a year's study of the region and left Cambridge on November 17, 1908. In England consultations were held with Sir David Gill and Sir William Morris, at that time the highest authorities on the climate of South Africa.

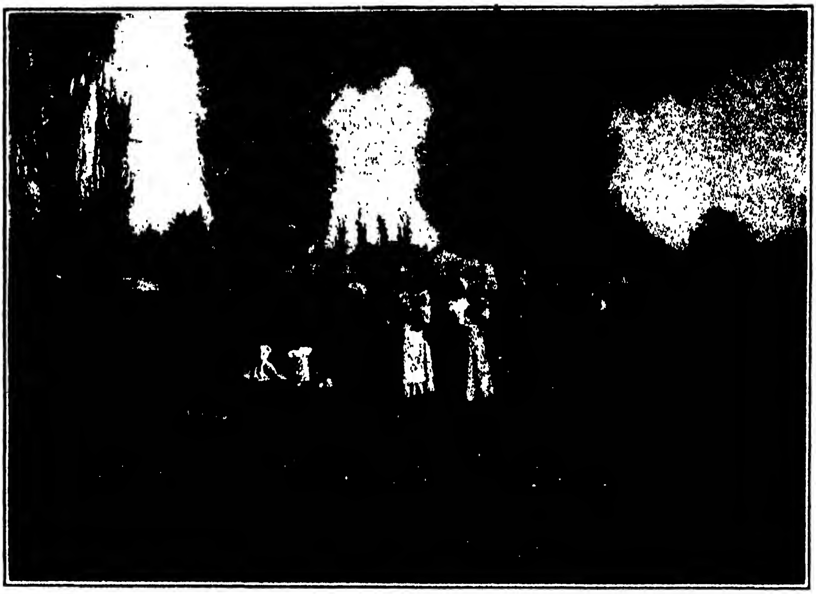
Cape Town was reached on December 22. As a place of residence Cape Town is charming. The scenic effects are very striking. The city lies along the curving shores of Table Bay and immediately at the foot of Table Mountain which rises abruptly to a height of 3,500 feet. The suburbs are also especially attractive, made more so by the fine groves of oak planted long ago by the Dutch settlers. The Royal Observatory is situated a few miles from the town. Although much valuable astronomical work has been accomplished at this observatory, the site on comparatively low ground near the sea seems unfavorable.

If we except the more or less narrow coast lands lying near the South Atlantic and Indian Oceans, South Africa is a vast tableland. Included in the coast regions are rich and fertile areas having sufficient rainfall for the purposes of agriculture. In general,



HARVARD TEMPORARY STATION, HANOVER

however, irrigation is necessary. The conditions vary enormously, often within short distances, owing to the influence of adjacent or intervening mountains. From Cape Town going by rail to the northeast one passes successively through the southern Karroo, having an elevation of about 1,500 feet, then through the middle Karroo, having a somewhat greater elevation, until the Great Karroo is reached which extends northward at an elevation of from 4,000 to 6,000 feet. These great interior regions are semi-arid, but they vary much in different localities. In the west, especially, are stretches of almost complete desert, while in other parts considerable rainfall occurs. Only a scant population is possible, unless under artificial conditions such as those brought about by gold and diamond mining. In general, the region is suitable for grazing rather than for agriculture, except in the comparatively insignificant areas where irrigation can be employed. The soil is good, but not only is the rainfall scant and irregular, but it frequently comes in heavy downpours, the accompaniment of violent thunder storms; so that, in addition to the loss of water, which runs away rapidly over the sun-baked earth and is lost, great damage is caused by erosion. The vast stretches of plain, generally known as *veldt*, are parched and apparently dead in the dry season, but are often green and beautiful in the rainy season. Each farm must have its natural spring (*fontein*) of water for domestic and farm purposes. This is frequently supplemented by dams constructed at large expense to retain the rainfall, and sometimes by artesian wells. These great farms support thousands of sheep and cattle which subsist without



A Street in Hanover

difficulty on the sparse bush and grass of the veldt, provided there is an abundance of water for drinking. In exceptionally dry years, however, the supply may fail and then the cattle perish in great numbers. Farther north in Rhodesia is a region of greater rainfall and much more pleasing appearance. Instead of arid plains beautiful groves of trees are interspersed with grassy glades.

Somewhere on this great plateau was to be found the locality most suitable for astronomical observation, and the first step appeared to be to take a general view of the different parts. Cape Town was left, not without regret, and Worcester was reached in a few hours. This small city, 109 miles from Cape Town, at an elevation of 800 feet, is perhaps the most desirable site for astronomical work near the coast. It is situated in a large arid valley not far from the base of the Hex River Mountains. It is well supplied with water brought from the Hex River, a tributary of the Breede River. The valley is surrounded by mountains rising from 3,000 to 6,000 feet. The climate is in general very agreeable, although somewhat hot in summer. Occasionally the temperature attains 100° F. A maximum even as high as 104° has been recorded. In winter the temperature rarely falls to the freezing point.

The next site to be seriously considered was Hanover, four hundred miles to the northeast on the Great Karroo at an elevation of about 4,500 feet. The train by which this trip was made was of the English compartment class, and comfortable when not crowded. One is much impressed with the vast stretches of arid lands apparently but little inhabited. For hundreds of miles no town of much

THE VILLAGE OF HANOVER

importance is passed. Although the large farms generally lie in the background out of sight, the amount of business they do with the railway must be small, if one can judge by the appearance of the stations along the railway. In such a country one train a day is sufficient for all the passenger traffic, and this goes forward by night as well as by day. This involves the possible arrival at one's station at any hour of the day or night. My train reached Hanover Junction at 12:30 A. M. From the junction to the village of Hanover is nine miles. This trip was accomplished at that time in a "Cape cart," a two-wheeled wagon having two seats, the one in front for the driver and a possible passenger. The wheels of the Cape cart are very large and the body correspondingly high. A Boer lady shared the rear seat with me. We were so completely shut in by the low cover, the closed sides, and the persons in front, that even by daylight it would have been difficult to see anything of the scenery. As it was, I could not even see the faces of my companions. The cart was drawn by horses over a road by no means smooth, and one hesitated to conjecture what would be the result of an overturn. Apparently this never occurs. We arrived at the only hotel in Hanover at about two A. M. Not a light was anywhere visible. The driver opened a door on the porch, lighted a candle and left me. This seemed rather an unceremonious entry, but as there were two beds in the room, I selected one and retired. On the following day the proprietor and his wife appeared and did all in their power to make my stay comfortable.

"KOPJES" AND "VELDT"
Hanover in the background.

Hanover is a small town on the Great Karroo, about 500 miles distant from Cape Town by rail. It lies in the midst of a nearly level expanse of semi-arid veldt. At the time of my visit it had perhaps 500 white residents and about as many black inhabitants. The latter were referred to as Kaffirs, although their racial characteristics were somewhat mixed. The Kaffirs lived in a section by themselves known as the "location." At nine P. M. a bell was rung and they left the town proper and were not expected to return until after daylight the following day. Upon one extremely tall and slender policeman rested the obligation to enforce this and all other laws. Good order was everywhere maintained. During my residence in South Africa I wandered about in this and other towns at all hours of the day and night without the least affront. In Hanover it was not considered respectable to keep the Kaffirs in one's house, even in the case of domestic servants. The village itself was rather picturesque and attractive with its brick or whitewashed houses placed in large gardens.

The early Boers were a rude but heroic race. Incensed by what they regarded as the tyranny of the British government at Cape Town, they "trekked" into the little known regions to the east and northeast, fighting their way against black savages and always comparing themselves to the Children of Israel in their flight from Egypt to the Promised Land. In their migrations each natural spring of water became the site of a household. Without this spring the development of a farm home would have been impos-

A SOUTH AFRICAN FARM
Hanover district.

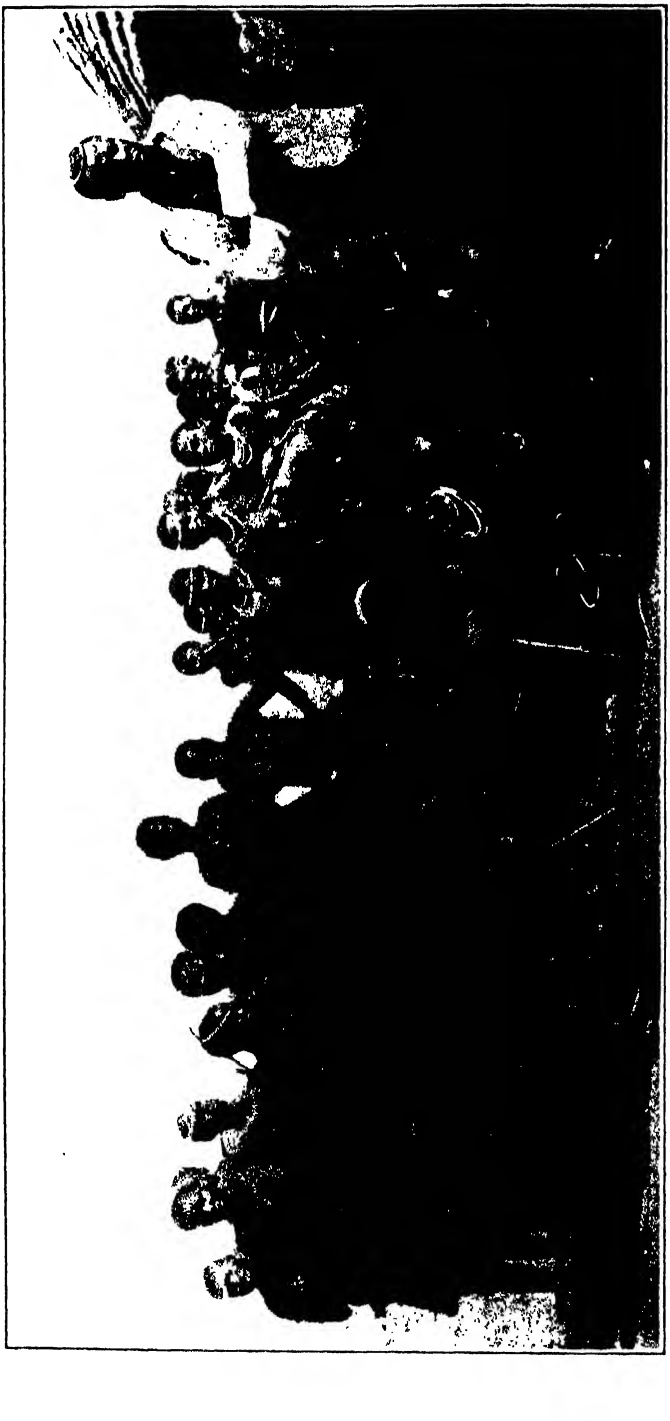
sible. Hanover owes its existence to an unusually abundant spring. This is situated on a low hillside near the village and provides a daily supply of about 250,000 gallons, an amount which varies little, whatever the season. Originally the water flowed to the town in an open stream and every family went to this stream for its household needs, and the balance was used for irrigation. Owing to a serious epidemic of typhoid fever, which occurred before my arrival, caused probably by a pollution of the supply, the spring was closed in and the water was piped to the town. Even then no pipes were allowed to enter the houses for fear lest some families might use an unfair amount of water. Faucets were placed in the streets, however, where each family might obtain sufficient for domestic use. The balance, a small but continuous supply, was devoted to the irrigation of the gardens. Each original proprietor was allowed this limited amount for a certain hour of the day or night once a week. More recent householders residing in the outskirts of the town received none of the water for irrigation, but in some cases availed themselves of shallow artesian wells which provided a rather limited supply. It is hard to see how a larger population could be provided for, unless possibly by better artesian wells.

At this time a visit was paid to Bloemfontein, where the conditions appeared to be similar to those at Hanover. Bloemfontein, however, as the capital of the Orange River Colony, had much to offer in the way of social and educational advantages. Kimberley

A BOER FAMILY ON THE MOVE

was also visited. It lies about two hundred miles north of Hanover and to the west of Bloemfontein. Except for the presence of the diamond mines which cause the ground in their vicinity to be torn up by the open workings, and the uncertainty as to the future of such a region, the conditions appear to differ little from those at the other towns referred to. The same may be said also of Johannesburg, which has the advantages which go with a large city and especially the presence of an established observatory. As one goes farther north the cloud and rainfall slowly increase. The trip was extended to Buluwayo in Rhodesia, a much fairer country than that to the south.

While at Buluwayo a visit was made to the Victoria Falls, a short distance to the northwest. The Zambesi is the largest river in this whole region. It flows through a forested country in a generally easterly direction along the plateau. The falls are caused, not by any falling off in the level of the plateau, but by an enormous transverse cleft or chasm lying in the path of the river which is here about a mile in width. The chasm is nearly 400 feet deep and its width is about as great as its depth. Confined in this narrow gorge, the waters of the river have for exit only a narrow opening, in one place about 300 feet in width. This outlet is known as the cauldron. Below the falls the cañon through which the river runs is narrow and tortuous. The roar of the cataract is audible for many miles, and the mists which rise above it can be seen from a long distance. It is easily one of the world's scenic wonders. An observatory founded near this great natural phe-



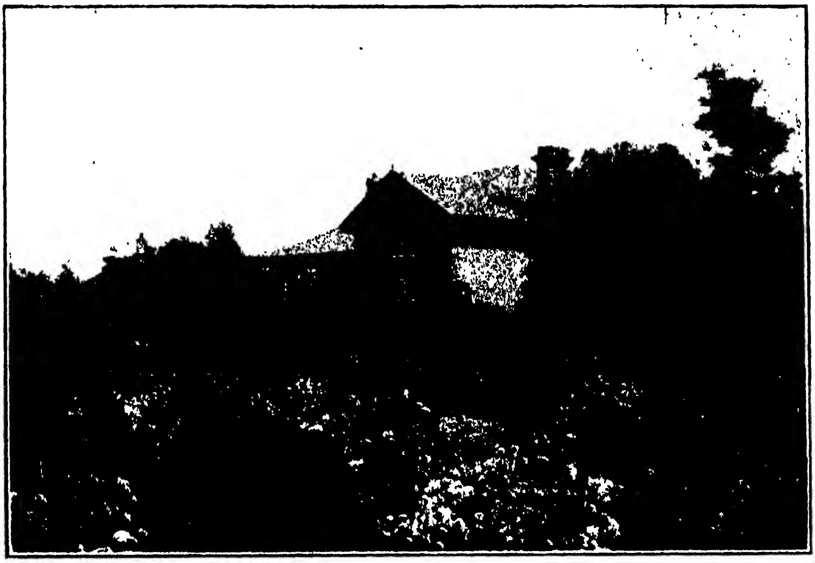
A Kaffir Chief and his Family

nomenon might perhaps be invested with a certain romantic sentiment. The region, however, is evidently more cloudy than the barren plateau a thousand miles to the south.

A somewhat hasty survey of the whole region having thus been made, it became necessary to decide upon the site of the main station for the year's program. Hanover was selected for the following reasons: In the first place, in the opinion of Sir William Morris, who had made observations for geodetic purposes over the whole region, Hanover offered the best conditions of all the places which he had visited. From a purely astronomical standpoint, this view was shared by Dr. R. T. A. Innes, director of the Johannesburg Observatory. No one whom I consulted believed that Hanover was surpassed in this respect by any other locality, although other sites were thought to be about the same. For a permanent observatory some weight should probably be given to such considerations as the advantages of a large city and the presence of an established observatory, such as that at Johannesburg. For our temporary expedition such considerations were of less importance. Rhodesia was rejected, since undoubtedly it was more cloudy than the region farther south. Kimberley was considered unfavorable on account of the vast diamond workings, and Johannesburg on account of the still vaster gold-mining activities. Bloemfontein and Worcester were chosen as secondary stations, and arrangements were made for occasional trips to these places in order to test the seeing and to assist in the observations. Voluntary services of great value were given in the former place by Mr. James Lyle, and in the latter place by Mr. Izak Meiring.[1] Hanover is situated conveniently between these two towns.

Regular work was begun at Hanover early in February, 1909. In addition to the meteorological observations, astronomical observations of southern stars were carried on, not only for the results themselves, but as the best possible test of the astronomical conditions. A small observatory was established on the edge of the town without expense for the site through the kindness of a local club. The equipment consisted of an 8-inch visual telescope, a 5-inch visual telescope, and a small photographic instrument devoted chiefly to long exposures on the southern Milky Way. In addition, for use at the three stations, photographic instruments were provided with which equatorial stars were photographed each clear night as a test of the clearness and steadiness, and exposures were

[1] In addition to those whose names are given in the text and others, the thanks of the expedition are due especially to H. E. Sir Walter Hely-Hutchinson, then Governor of Cape Colony, and to the officials of the British South Africa Company.



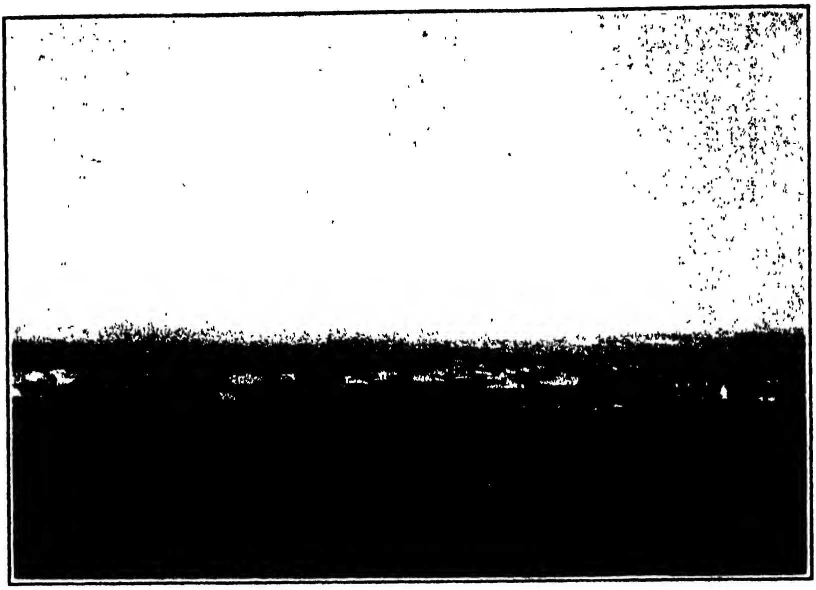
BLOEMFONTEIN. RESIDENCE OF MR. JAMES LYLE.

made for several hours on polar stars as a check on the cloudiness. Altogether at the three stations about 1,500 plates were obtained.

The mayor and other Dutch officials of Hanover received me with cordiality, and the few English and Scotch residents were most hospitable and kind. My life there, which otherwise would have been somewhat lonely, was made so pleasant that it stands out as one of the especially bright spots in my life in foreign countries. So much so that even now the thought of that lonely little town almost lost on the wide expanse of veldt, and of those who received me in such a cordial and informal way, causes an odd quickening of the heart.

The pastor of the Dutch Reformed Church did not call, and I inferred from various reports that he had serious doubts as to the reconciliation of science and religion. The pastor of the colored church called, however, and without revealing his identity asked me many questions about the instruments and work. He made few comments, but later preached a sermon in which he advised his congregation to keep away from the observatory, a bad and even dangerous association for Christians.

In Hanover an astronomer was an unheard-of novelty. I became known at once as "The Professor." A lady of my acquaintance remarked to her small sons one day, "Here comes Mr. Bailey." "Oh, no, it isn't," replied one of them, "that is The Professor." The professor was reputed to be able to foretell all sorts of natural phenomena, a reputation very difficult to maintain.



Bloemfontein from Signal Hill
Showing Brandkof, a hill suitable for an astronomical station.

In common with other small South African towns Hanover was afflicted with house flies during the hot season. Sanitary conditions were not of the best. In the hotel where I lived flies swarmed from outside into the dining room, since neither windows nor doors had screens. It was necessary to eat with one hand and to brush away the flies constantly with the other. A lady remarked to me that in spite of the greatest care she could always feel flies buzzing about in her stomach.

Occasionally for exercise I walked entirely around the village on the open veldt, and sometimes a small but exceedingly fleet deer was seen. At that time game had been preserved to some extent and partly domesticated on the great farms, where it was systematically hunted at stated seasons.

The following table gives the results for the night cloudiness at Worcester, Hanover and Bloemfontein, as derived from the photographs of equatorial and polar stars. The months have been placed in their usual order, but the observations really extended from March, 1909, to February, 1910, inclusive. The surprising equality in the cloudiness recorded for the three stations is the most striking feature. While this accordance is doubtless greater than would generally be found in the results for any one station in different years, and hence is partly accidental, it seems certain that there is little to choose between the three stations in the matter of cloudiness. The mean cloudiness at Hanover at eight P. M., was 3.8.

The result for the whole twenty-four hours would differ slightly from these values. It should be noted that while the cloudy and rainy season at Hanover and Bloemfontein is in the southern summer, at Worcester no such distinction is found. If means values for a series of years were used it is probable that the resulting cloudiness would be nearly uniform throughout the year. This result might be expected, since Worcester is situated between Cape Town, where the cloudy season is in the southern winter, and the towns on the Karroo, where it occurs in the summer. For the same year the mean cloudiness for Arequipa was 5.6, the different months ranging from 3.0, July, to 9.2, December. On the scale employed, 0 indicated a clear sky, and 10, one completely cloudy.

TABLE 1

South Africa. Night Cloudiness. March, 1909, to February, 1910

Month	Worcester	Hanover	Bloemfontein
January	2.2	4.0	4.0
February	4.1	6.0	4.7
March	3.6	3.4	4.3
April	3.3	2.8	2.4
May	2.8	3.4	4.1
June	3.2	2.2	1.3
July	2.7	1.4	1.6
August	3.5	2.7	2.9
September	3.4	2.6	2.3
October	4.7	3.1	3.6
November	3.7	3.6	4.1
December	3.8	5.9	4.3
Means	3.4	3.4	3.3

Table II gives, for the same months as in Table I, the results of the observations of temperature at Hanover, expressed in degrees Fahrenheit.

The diurnal changes in temperature at Hanover as shown in the table are severe. The records of the mercurial thermometers are in general checked by the records of the thermograph, although the range is a trifle less by the latter instrument. The thermometers were read at two P. M. and at eight P. M., since the observers often worked until late at night and were not on duty in the morning, but details of the changes are available from the thermograph sheets. During the winter the temperature in the late night often fell to 20° F. and in a few cases to 14° F. By afternoon of the following day it sometimes rose to 60°, or even to 70°. In summer, while the days were often very warm, heavy clothing was needed in the late night. On this account the people of Hanover, who in general were without the means for providing their homes with

Kimberley. Diamond Mine: Blasting the "Blue Rock"

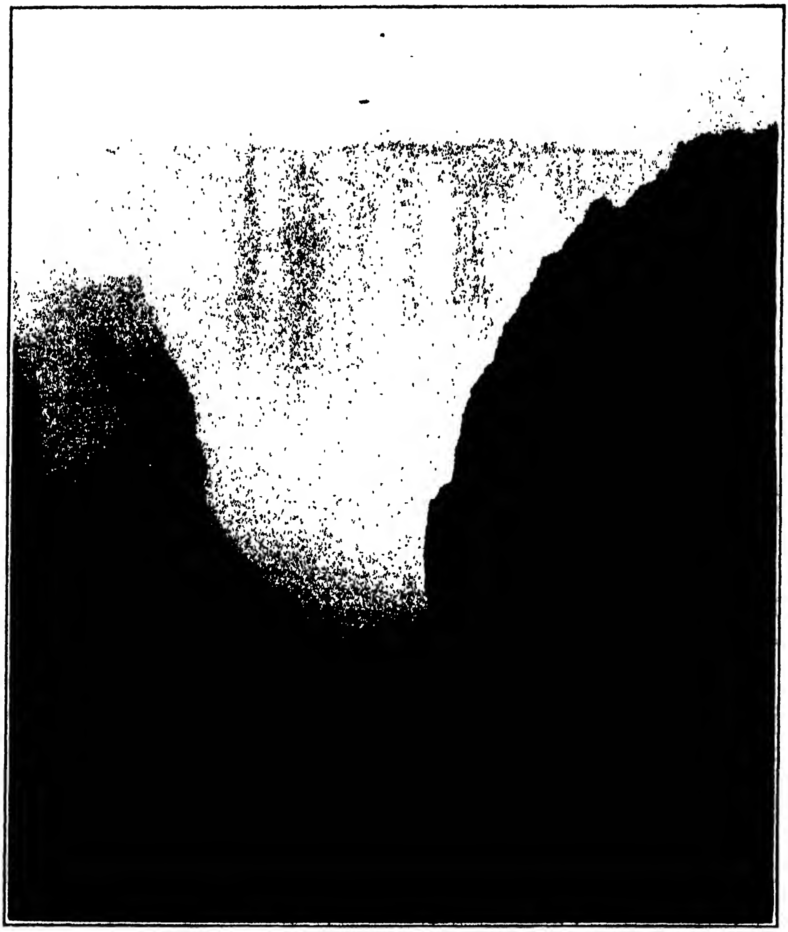
TABLE II

SOUTH AFRICA. HANOVER. AIR TEMPERATURE

Month	Max.	Min.	Mean Max.	Mean Min.	Daily range Max.	Daily range Min.	Daily range Mean
January	100°	40°	88°	54°	47°	20°	34°
February	92	45	83	55	40	10	28
March	84	39	77	48	42	22	29
April	82	31	73	45	42	8	28
May	72	26	65	37	41	8	28
June	68	14	64	28	49	8	36
July	69	14	62	25	50	18	37
August	80	16	68	28	55	18	40
September	89	18	73	36	53	19	37
October	90	26	77	39	55	23	38
November	93	36	84	44	51	12	40
December	95	42	84	49	52	13	35

artificial heat, retired early in the evening to escape the cold, and became active again only after the morning's sun had made life more comfortable. There were no street lamps, thus making the locality ideal for astronomical observations. During the daylight hours the relative humidity was generally rather low, often no more than 30 or 40 per cent., or even less, but at night it rose rapidly in a few hours to 90, or even to saturation on unfavorable nights. Under such circumstances the deposition of dew or frost caused considerable inconvenience. This trouble was aggravated by the exposed condition of the instruments, which were unprotected when the sliding roofs of the shelters were removed. In some cases the steel tube of the 8-inch telescope was covered with a thin coating of ice.

A mean diurnal range of temperature, varying in different months from 28° to 40°, with a yearly mean of 34°, seems somewhat extraordinary. It is probable that the year during which these observations were made was one of exceptionally large extremes, and that in general somewhat milder conditions might be expected. The general truth of these results, however, is checked not only by the records of the thermograph but by observations made under the direction of the Meteorological Commission of the Cape of Good Hope in other years. The annual mean diurnal range is nearly always greater than 30°. The extremes appear to be much greater at Hanover than at Worcester, as might be expected, but also larger than at Bloemfontein. At Worcester during two years' observations made by Mr. Meiring, the maximum temperature was 104° and the minimum, 31°. The mean daily range for the two years was 25°, varying between 31° in January and 19° in August. In Bloemfontein the highest temperature found in several years' rec-



VICTORIA FALLS. THE CAULDRON

ords was 99°, and the lowest 22°. The mean daily range appears to be about 27°, although the results depend on self-recording instruments.

In the vicinity of Hanover are several small hills rising abruptly from the plain like plums in a pudding. They are known as "kopjes." One of these, having an altitude perhaps of 250 feet above the plain, is situated at a distance of about a mile and a half from the village to the northeast. Some temperature experiments were made on the flat summit of this hill. Two thermographs were available for a comparison of the temperatures on the hill and on the level plain near the observatory. They were adjusted to read the same at 50°. From March 16 to May 10 one of them was placed near the observatory, and the other, on the summit of the hill. From May 11 to August 1 the instruments were interchanged.

The second period was largely during the clear winter season. Altogether, they give a fairly good test of the advantages of a site somewhat elevated above the plain. The mean results are shown in Table III.

TABLE III

South Africa. Hanover. Temperatures, Town and Hill

Maximum		Minimum		Range		
Town	Hill	Town	Hill	Town	Hill	
°	°	°	°	°	°	
72.3	70.7	46.8	49.0	25.5	21.7	March 16 to May 10
62.7	60.7	29.9	38.1	32.1	22.6	May 11 to August 1
67.5	65.7	38.4	43.6	29.2	22.2	Whole period

The advantages of a site on the summit of a hill appear to be considerable. During about four and a half months, the maximum temperature was higher on the hill than on the veldt on only two days, and the minimum temperature was lower on nine nights. The maximum temperature was the same at both stations on twenty days and the minimum the same on thirteen nights. On all other occasions the maximum was lower and the minimum higher on the hill, thus giving a mean daily range of temperature for the whole period less by about 7° than that on the plain.

Many observations to determine the quality of the "seeing" were made in different localities. The scale devised by Professor William H. Pickering was used. It is described in Harvard *Annals*, 82, 31. It runs from 1 to 10, 1 being used for extraordinarily bad conditions when the star's image is very large and shows no diffraction disc or rings, and 10, when both disc and rings are sharp and stationary. The scale is intended for use with a five-inch telescope and a one quarter-inch eyepiece. I have seldom, if ever, seen definition which seemed to me to deserve 10. Observations were made at Worcester on nine nights in various months. The best conditions observed were recorded as 8, the average for stars of altitude 30° or more being 6.4, and the lowest for such stars 5. Near the horizon the poorest record was 3. At Hanover observations were made on twenty-five nights. The best seeing was recorded as 9, which often occurred. The average for stars above 30° was 7.7, and the poorest for such stars 5. Stars near the horizon were called 3 in a few cases, but usually 4 or higher. At Bloemfontein observations were made on ten nights. The best seeing was called 9, the mean for stars above 30°, 7.3, and for stars near the horizon sometimes 3 but usually 4 or higher. A few observations also were made at various other localities. At Johannesburg the seeing, so far as can be judged by observations on two nights, compares favorably with that at Hanover and Bloemfontein. At Buluwayo the seeing was fair but somewhat less favor-

VICTORIA FALLS
From the northern bank.

able. At Cape Town the seeing was inferior to that in the other places examined. The highest record was 7, and at times the record was from 1 to 4. It should be stated that observations were made on only three nights and these in December. A southeast wind seemed to affect the seeing badly.

In addition to the amount of cloud, the polar and equatorial plates made at Worcester, Hanover and Bloemfontein served for a determination of the transparency of the atmosphere. The examination shows no perceptible differences between Hanover and Bloemfontein. Equally faint stars appear on the photographs at these two stations. At Worcester, however, there is shown a distinct loss, compared with the other two stations, amounting to half a magnitude or more. This photographic result confirms visual observations. That the sky is darker and the stars more brilliant on the plateau than at a lower altitude near the coast has been observed by many. Worcester has considerable in its favor for an observer who does not need the utmost possible in the way of faint objects. The atmosphere is undoubtedly less transparent than on the plateau, but on the other hand the amount of cloud is small and is more evenly distributed throughout the year than at either of the other stations. The climate is mild and the city offers all necessary advantages for comfortable living. It is not far from Cape Town. Expenses would probably be less than elsewhere, both for installation and maintenance.

The high plateau of South Africa offers many inducements for the establishment of an observatory for the study of the southern sky. The conditions are good over a wide area. If such an observatory insists on the social and educational advantages of a large city, Johannesburg will be chosen. It has also the added attraction of the presence of the Union Observatory.

Hanover and Bloemfontein appear to be more or less equal from the purely astronomical standpoint. The cloudiness and transparency of the atmosphere are about the same. The extremes of temperature may be considerably larger at Hanover, although these might be avoided in part by the selection of a site on the summit of a hill. The seeing may be a little better at Hanover and dust storms less frequent. Taken from all considerations, however, Bloemfontein seems preferable and is probably not surpassed by any other locality in South Africa as a site for an astronomical observatory.

RADIO TALKS ON SCIENCE[1]

FERTILIZERS FROM THE AIR

By Dr. F. G. COTTRELL
FIXED NITROGEN RESEARCH LABORATORY, U. S. DEPT. OF AGRICULTURE

Out of the 87 chemical elements known to us only about a dozen enter into the composition of most plants, and of this dozen there are only three which ordinarily come into consideration in the fertilizer problem, as the others are almost always available to plants in sufficient quantities. These three elements in which the whole fertilizer problem centers are phosphorus, potassium and nitrogen.

Phosphorus and potassium were widely and generously distributed in the igneous rocks of the earth's original crust and they have come on through and are found in larger or smaller proportions almost everywhere. Their story as normal soil constituents is therefore essentially a mineralogical one.

The case of nitrogen is, however, quite different. The two atoms of nitrogen making up the molecule of this inert gas which constitutes four fifths of our atmosphere have such a tremendous affinity for one another that it is only under very special conditions that they can be separated and made to combine with other elements to form compounds which can enter into the soil and be taken up by plants. This process, however, is absolutely necessary to life as we know it on the earth, because none of the plants with which we are ordinarily familiar seem to have the power in themselves of directly utilizing the free and chemically uncombined nitrogen in the air which lies all about them but must rely wholly on absorbing it in compounds through their roots.

On the other hand, when we try to trace back to their source the nitrogen compounds in nature, whether these be in the so-called humus of the soil, the coal measures, the petroleum beds or the nitrate deposits of Chile, we almost invariably find the trail leading us to a vegetable origin.

Thus we are brought to the seeming paradox that combined nitrogen in nature is all of plant origin and yet plants as we know them are incapable of forming compounds out of the nitrogen of the atmosphere which is apparently the only original source of the element.

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of Mr. W. E. Tisdale.

Like most paradoxes the answer to this one is to be found in the limitation of our acquaintance with the facts. Plants as we ordinarily know them are only a part of the vegetable kingdom. There is a vast host of marvelously important plants all about us, the individuals of which we can never see except under a powerful microscope, and it is through certain very definite species of these, the so-called nitrogen-fixing bacteria, that we now believe practically all the millions upon millions of tons of chemically combined nitrogen on earth have been slowly built up through the ages, out of the chemically free or uncombined nitrogen of the air.

It must be remembered, however, that the bacteria, though belonging to the vegetable kingdom, contain none of the green coloring matter called chlorophyl so can not derive their necessary life energy from sunlight nor build up starch or sugars out of water and the carbon dioxide of the air as do green plants. They must, on the other hand, subsist on such compounds built by the green plants and in exchange pass on to these latter the nitrogen compounds so essential to all.

Thus we see here again beautifully illustrated the endless interdependence of everything in nature.

Among these nitrogen-fixing bacteria, we find it convenient to distinguish two chief classes. The one (typified by the genus azotobacter) grows freely in most soils independent of any particular species of other plants, but it feeds upon the organic matter of the soil and ordinarily consumes the equivalent of from fifty to five hundred times as much sugar or starch as the weight of nitrogen which it "fixes" or puts into combined state from the air. The other class (typified by the species radicicola) will grow and thrive only on the roots of certain higher plants, namely, the legumes or pea family. In this case the green plant or host draws not only its own energy from the sunlight, but also that needed by the bacteria and passes this on to the latter in the form of food, receiving in return its quota of nitrogen compounds.

Under average soil conditions the azotobacter type of organism in the course of an ordinary growing season probably adds something like five to ten pounds of nitrogen per acre to the soil, whereas radicicola growing vigorously on the roots of a good field of peas, beans, clover or alfalfa may fix ten times this amount. Both forms are almost universally present to some extent in all soils and thus like any other crop only need to be given favorable conditions to multiply and furnish a large yield of fixed or combined nitrogen.

The old Romans, even though they knew nothing of nitrogen or of bacteria as such, were fully aware that the growing of legumes increased soil fertility and definitely practiced this as a part of their fertilizer policy.

Remembering the vegetable origin of coal it is evident that we are ultimately indebted to bacteria for even the nitrogen we recover in the form of ammonium sulphate from the destructive distillation of coal in our by-product coke ovens and city gas works.

We are not quite so sure about the great Chilean deposits of sodium nitrate, but an ultimate bacterial origin for even these seems at least as probable as any other yet suggested.

These nitrate fields of Chile, from which the first shipments were made about 1830, have long been the world's chief source of nitrogen both for commercial fertilizers and for explosives. Next in importance has come the sulphate of ammonia recovered from the distillation of coal as already referred to.

Up to a decade before the World War practically all the other nitrogen used in fertilizers came from animal or vegetable wastes, such as stable manure, slaughter house tankage, fish scrap, guano, cotton seed meal and the like.

But in 1902 a new era dawned in man's control of this very important department of material resources. In that year Bradley and Lovejoy, two American chemists, set up at Niagara Falls the first little apparatus ever definitely built to artificially fix atmospheric nitrogen for commercial purposes. It was based on the principle that when a powerful electric discharge or arc, as we call it, takes place in air some of the oxygen and nitrogen which were previously only mixed but not chemically combined, become in the intense heat of the arc chemically combined, and if their recooling is quick enough will remain combined. These oxides of nitrogen can then be absorbed in water to form nitric acid and, neutralized with lime, soda or potash, to form the corresponding nitrates, all of which when properly introduced into the soil are excellent fertilizers.

In every lightning flash there is undoubtedly some nitrogen fixed in this way and washed down out of the air to the soil by the rain. This process, of course, antedates even the bacteria and may have furnished some of the necessary compounds out of which the first bacteria arose, but to-day it supplies a negligible amount in comparison with that being constantly fixed by these organisms.

It is interesting and instructive to note that exactly this same electrical method was used and thoroughly described, including the chemical reactions involved by Cavendish in England, 150 years before, in his classic work on the composition of air, but its commercial application had to await the development of our modern hydroelectric industry to bring the cost of the process within the range of economic interest. Even the Niagara plant did not prove commercially successful, but the next year experiments were begun in Norway with even cheaper electric power and improved equip-

ment, and in 1905 the first commercially successful plant began operations there and is still running.

This process, however, consumes such enormous amounts of electric energy per pound of nitrogen fixed that it is only of interest in very special cases and as far as new installations are concerned may now be considered as having been completely superseded by other more modern and efficient processes.

Of these the one which followed immediately on the heels of the arc was the cyanamid process, which requires only about one quarter as much energy as the former. The first step in the cyanamid process and the one consuming most of the energy is the manufacture of calcium carbide in the usual way; *i.e.*, by melting coke and lime together in an electric furnace.

The resulting calcium carbide is then crushed to fine powder and treated at a red heat with pure nitrogen made from liquid air. The nitrogen combines directly with the calcium carbide to form calcium cyanamid. This can with certain restrictions be used directly as a fertilizer, but its possible application under American agricultural conditions is somewhat limited. It is more practical on a large scale to treat it with steam and alkali to form ammonia, or with weak acid solutions to form urea, both of which can find practically unlimited use as fertilizers if produced cheaply enough.

The cyanamid process reached the height of its success at the time of the World War, and is now being rapidly superseded by still more modern and more efficient processes.

It was known to the rest of the world even before the outbreak of the war that the Germans had perfected a new process which would probably supersede the cyanamid method for fertilizer and explosives purposes, as its power requirements were only about a quarter of those of the cyanamid, but nowhere outside of Germany was there sufficient detailed knowledge of it to permit the erection of large plants on this principle with any confidence of immediate successful operation. Yet the urge of war necessity made immediate action imperative. The great cyanamid plant at Muscle Shoals is one of the results. The $50,000,000 water power project there in connection with this, which will not be completed and ready for operation until next August, is, of course, a permanent, thoroughly useful and up-to-date asset, but the $70,000,000 cyanamid plant which was completed and tested out just at the close of the war was built frankly as a war emergency with full realization of how fast the industry was advancing and the consequent likelihood of this plant rapidly becoming obsolete.

Since the termination of the war we have learned much about the new German or Haber process for the direct synthesis of ammonia from its elements hydrogen and nitrogen, and the more we

learn of it both from others and through our own experiments, the more obvious does it become that it must inevitably supersede the cyanamid process for fertilizer and explosives.

At Muscle Shoals during the war the government also spent some $12,000,000 in the erection of a Haber type plant estimated at one fifth the capacity of the huge cyanamid plant. This direct synthetic ammonia plant was frankly an experiment and as a matter of fact was never put into successful operation. Its electric power requirements are so small compared to the other processes that its close association with the water power development has no special significance. The economic affiliations of this process are more naturally with coal mining and coke ovens, since the chief raw material it consumes would be either coke or coke oven gas, depending on which of two alternative procedures was used in preparing its hydrogen supply, which is the largest single factor of cost in the operation.

Briefly and very generally stated, the process itself consists in compressing a mixture of one part by volume of pure nitrogen and three parts by volume of pure hydrogen to a very high pressure, and then passing this mixture at a dull red heat through what is called a catalyst. The catalyst is a granular mass of specially prepared metallic iron containing small percentages of such substances as potassium aluminate called promoters. The preparation and protection from injury, both chemical or thermal, of this catalyst is one of the very delicate details of the process, and has required a great deal of research, as have also the engineering features of the process, involving as they do the handling of large volumes of gases through complicated operations at high pressures and temperatures.

But chemical engineering has already surmounted these difficulties and it is estimated that this year will see some 44 per cent. of the world's supply of inorganic nitrogen produced by atmospheric fixation as aginst 10 per cent. immediately before the war. Furthermore while this 10 per cent. was made almost wholly by the arc and cyanamid processes, nearly 70 per cent. of this year's fixation will be through the direct synthesis of ammonia.

THE CHEMICAL—ALCOHOL

By Dr. H. E. HOWE

WASHINGTON, D. C.

"HAVE you seen Al? Al who? Alcohol. Kerosene him last night, gasoline up against a lamppost and took a naphtha. He hasn't benzene since."

But the question is altogether too general. You must indicate which one of the many alcohols you mean. The chemist knows a large family of them, each with its own personality and special occupation. In composition they are somewhat similar, all being made from carbon, hydrogen and oxygen, but the proportions of these constituents differ and the arrangement of the atoms in the molecule makes all the difference in the world both as to characteristics and the use of the alcohols.

To the non-chemist alcohol always means grain or ethyl alcohol, and if he is a bit careless he may include wood or methyl alcohol under the same general name. This practice has led to the adoption by scientists and the trade of the word "methanol" for methyl or wood alcohol, to prevent the uninformed from confusing these two principal alcohols of commerce. Butyl and propyl alcohols are growing in industrial importance, but are less likely to be misused as a beverage.

By far the greatest production is of the ethyl or grain variety, for which waste molasses of sugar refineries, corn and in Germany potatoes are the principal raw materials. The conversion of starches to sugars and of sugars to alcohol involves technical processes requiring careful scientific supervision, while the distillation of the weak solutions of the alcohol thus formed to yield the alcohol of commerce is an engineering feat.

The general public may not be familiar with alcohol as a chemical, but nevertheless its use as such dwarfs into insignificance any other application of this material. In making solutions of substances as a step in manufacture, alcohol occupies a place of importance second only to water. There are a host of substances that can not be dissolved without it, including such familiar things as vanilla extract, a long list of shellacs and varnishes, the solutions of essential oils which we know as perfumes and many of the tinctures and extracts of medicine and pharmacy, where it is also used to dilute medicinal preparations and to preserve some of the active principles employed in medicine. In the manufacture of liquid soaps, in the preparation of shoe blacking and dressings, non-corrosive soldering fluxes, inks and disinfectants, in the silvering of mirrors and in making cleaning solutions, the chemical, alcohol, finds employment. Because some things will dissolve in alcohol and others will be thrown out of solution in the presence of alcohol, it is an important reagent in many purification processes, its presence or absence enabling some separations to be made with precision. Alcohol is so necessary in the dye industry that its low price in Germany was one of the important factors in the establishment and early development of the synthetic organic chemical industry in that country, as opposed to Great Britain where the first coal-tar color was dis-

covered but where a heavy tax on alcohol interfered with the development of that industry.

To enumerate all the uses of alcohol as a solvent would require the entire time at our disposal, for the list for which the government has prescribed special formulas of denatured alcohol and for the use of which permits are issued covers some five or six pages of closely printed matter. Among the uses of alcohol, however, are the following: artificial flowers and feathers, brushes, bronze powders, confectioner's colors, dental alloys, embalming fluids, enamels, fertilizers, incandescent lamp filaments, fireworks, gas mantles, hats, imitation ivory, japans, jewelry, mucilage, non-shatterable glass, lubricants, photographic engraving, photographic films, paper, refining precious metals, shampoo liquids, shoe polish, solidified alcohol for fuel, stencil paper, transparent paper, trinitrotoluol, celluloid and pyralin, synthetic camphor, furniture polish, smelling salts, imitation rubber, certified food colors, liniments and lotions for external use only, tincture of iodine, tooth paste, dentifrices and barbers' supplies.

The chemical, alcohol, may also be classed as a raw material in chemical processes. It is used to produce chloroform, iodoform, acetic acid, vinegar, ether, ethylene and the whole family of ethyl compounds which are used in turn for the production of artificial leather, varnish removers and a variety of commercial chemical compounds. For example, one of the largest manufacturers of automobiles is the largest user of ethyl acetate for the production of his artificial leather, which could not be made without ethyl or grain alcohol.

One of the greatest single uses of denatured alcohol is as an antifreeze solution for automobile radiators. A mixture of alcohol and water freezes at a lower point than the water alone, the proportion of alcohol determining how low a temperature can be withstood. An interesting chart has recently been prepared, showing the number of private passenger cars, motor trucks and cars for hire in the various states. The number of months of freezing weather in each state has been determined from the weather bureau records and from this information the number of gallons of alcohol required to operate these cars has been estimated. The total is slightly more than 28,000,000 gallons.

Alcohol bears another important relation to our transportation problem, namely, as a supplementary fuel ideally suited for use with gasoline. Alcohol possesses properties which enable it to act as an antiknock compound, giving something of the benefits which characterize tetraethyl lead, so widely discussed of late. Further, its use tends so to promote combustion as to keep the cylinders clean, and while its use alone does not give the mileage obtained

with gasoline with present-day engines, motors can be designed to employ alcohol economically.

Early experiments with alcohol in gasoline were not satisfactory because the commercial alcohol contained enough water to prevent proper mixing with the motor fuel, and materials added to insure this mixing led to corrosion troubles. Through scientific research a commercial method has been perfected for producing alcohol free from moisture. This alcohol, known as anhydrous or absolute alcohol, mixes in all proportions with gasoline and thus removes the former difficulties.

From a motor fuel standpoint alcohol has the unique distinction of annual production, a point which should interest farmers who may soon find it profitable to develop and grow crops as raw material for alcohol motor fuel production. This has been the case in Germany where a potato containing too much starch to make it attractive as human food has proved a commercial success for alcohol production. In Central and South American countries large quantities of alcohol are made from molasses from sugar factories and, mixed with ether made from this alcohol, used to drive motors of various kinds, including those on plantation railways as well as business and other cars.

In recent years artificial silk has become an important item of commerce, and the industry has shown phenomenal growth. Some of the finest varieties of artificial silk are those involving a solution of a cellulose compound in alcohol and ether, though of course none of this solvent can be found in the final product. A single artificial silk mill in this country is now using in excess of 2,000,000 gallons of ethyl alcohol per year.

In medicine and in scientific research alcohol finds a multiplicity of uses. Much that has been accomplished in the study of bacteria, in the study of tissues and body cells and in the development of methods for identifying and later overcoming diseases, would have been impossible without the use of this chemical compound. It is used in biological staining, in the gradual removal of water from material for study under the microscope and for a list of practical applications which necessitate an adequate supply of pure alcohol in every dispensary and hospital.

The extended current reference to methanol in the newspapers is due to the successful production of this solvent within the last year from two gases, carbon monoxide and hydrogen, by a process similar to that used for the fixation of atmospheric nitrogen. This artificial or synthetic methanol is reported to be made much more cheaply than the natural product obtained by the distillation of hard woods. The producers of methanol in America have devoted more attention to increasing yields and purification of product than to research on new methods for the manufacture of methanol.

Abroad, lacking natural resources, emphasis has been placed on the synthetic production of this liquid. It affords an excellent example of how necessary it has become for industries generally to apply chemistry to their manufacturing processes and continually to conduct research that they may know as much as any one regarding their subject. Further, it is an interesting example of how science frequently comes to our aid in supplementing materials heretofore derived solely from natural resources that are now fast disappearing.

It is unfortunate that the press has questioned the poisonous character of the new methanol. There is nothing to justify the impression that it may be less poisonous than any other pure methanol. Physiological chemists tell us that whereas ethyl or grain alcohol is burned to carbon dioxide and water in the human body, methanol is not only difficult to burn completely but the products of its combustion include formic acid, which has a fatal effect on the optic nerve, causing blindness, and frequently causes the death of its victim. Rather than question the toxicity of synthetic methanol, its danger should be emphasized. A service can be rendered by sounding a special warning, for pure methanol is more difficult for the layman to detect, as it does not have the characteristic odor which usually is sufficient to frighten off a drinker.

It will be clear that the current impression of alcohol does alcohol the chemical a gross injustice. Scientists and the industries are interested in having the public appreciate something of the utility of alcohol, in stressing which it should be pointed out that a great deal of time and money have been spent in an effort to find a satisfactory and useful substitute—so far without success. Its proper development under impartial enforcement of existing laws will do much to acquaint the public with its proper place in science and the arts.

THE THUNDERSTORM

By Dr. W. J. HUMPHREYS

U. S. WEATHER BUREAU

When the weather is hot and sultry, and has been for two or three days, the blue sea of the sky becomes dotted here and there with mountainous islands of cloud, cumuli or summer cumuli, as we call them, snow-white on the sunlit sides and blue-gray over the shaded portions. After several hours of sunshine, and especially about mid-afternoon, one of these great woolpack masses, already of large size, grows faster than its neighbors and quickly raises its tumultuous top miles above the surface of the earth. Presently rain begins to fall from this great cloud. Then it and all the ele-

ments are rudely changed. Calm gives way to turbulent blast, and the erstwhile quiet and beautiful summer cloud becomes a dark and angry tempest.

Shortly after the rain begins the top of the towering cumulus reaches its greatest height and there often spreads out or is pulled out by swifter upper winds into a thinnish and more or less fibrous sheet that may extend far ahead of the storm itself. In this case, then, after the storm is fully developed and on its way the first evidence one has of its coming is the covering of the sky with a fibrous haze, whose tangled threads soon thicken to a high white canopy and that in turn to denser and darker cloud. In a little while now, if not already, one sees in the direction from which the storm is approaching, somber, mountainous forms, the cumulo-nimbus of the meteorologist, the tops of which may be hidden by the general cloud sheet. Already the sun is obscured and the excessive heat tempered a little by the gracious shade. But an oppressive stillness prevails —a solemn hush as before an unknown but impending doom. Presently distant lightning is seen near the denser portions of the cloud, and before long the faint rumble of thunder is heard.

As the storm draws nearer a grayish surf-like billow, the storm collar, passes overhead. A gentle breeze is felt blowing towards the oncoming tempest. A curious roll of scud whirls over and over along the forward base of the storm cloud just in front of the gray-blue curtain of falling rain. In a few minutes the warm inflowing breeze is replaced by a relatively cool outblowing gale, bending trees and driving dust and leaves before it. The lightning flies. The thunder roars. Big drops of rain fall, mingled perhaps with hail. Immediately the rain comes down in driving sheets, but in a few minutes the worst is over. In half an hour, more or less, the windward clouds grow thinner, the lightning becomes fainter and the thunder fades away. Soon the rain ceases entirely and the sun shines in a clean, clear atmosphere. All nature is refreshed and only a vanishing storm may be seen through the arc of promise—the gorgeous multicolored bridge of the gods.

Such is the glory and the grandeur of the thunderstorm. But how, we ask in our prosaic and inquisitive moods, is it produced? What causes it? Well, first of all, the air has to be humid. Rain can not be gotten from dry air any more than blood can be gotten from the proverbial turnip. Next, the water must be gotten out of this air in the form of rain, and that is done by forcing it up to high levels. This occurs whenever the lower layers are sufficiently warmer than those at considerable heights, a condition that can occur in more ways than one. The most obvious way, however, and the most frequent, especially in the warmer portions of the world, is by heating the surface of the earth through exposure to sunshine. This is why thunderstorms are more frequent in tropical regions

than elsewhere; more frequent in summer than winter and in afternoons than forenoons. The heated soil heats, in turn, the air next to it, both by contact and by radiation. This air, like all gases, expands strongly as its temperature is raised and thereby becomes lighter, volume for volume, than the air above it, not so warmed, would be if at the same pressure. Hence any little disturbance, such as the slightest breeze, starts these two masses of air, the warmer and the colder—the under and the upper—exchanging places. As this process, a sort of forced stirring, goes on, the atmosphere is gotten into such a state in respect to its change of temperature with height that a small increase of temperature at the surface causes the air thus warmed to be pushed up—to ascend, we usually say— to a considerable height.

As the humid surface air rises, it expands, because as it rises the load on it, that is, the weight of the air still above it is continuously decreasing. But all the time this load is considerable, roughly eight to fourteen pounds per square inch, and the expansion against it requires a correspondingly large amount of work. This work in turn is done at the expense of the heat of the expanding air, hence it must get colder, and it does so at the rate of about 1° F. for each 187 feet increase in height. Now, the amount of water vapor that can exist in a given volume, such as a cubic foot, rapidly decreases with decrease of temperature. Hence the rising humid air soon cools by expansion to what we call its dew point, or saturation temperature, that is, the temperature below which the water present can not all exist as invisible vapor. As soon, then, as the rising air, or, to speak accurately, the pushed-up air, has cooled below its dew point, cloud begins to form, and the higher this ascent the bigger and higher the cloud.

Right here another thing happens that is vitally important to the formation of the cumulus or woolpack cloud and the genesis of the thunderstorm. As the water vapor condenses into liquid there is set free the heat of vaporization, which prevents the rising air from cooling as much for a given ascent as it otherwise would. All the inner portion of the cumulus cloud therefore is warmer than the air at the same level on the outside. In short, the cumulus cloud makes of itself a sort of a heated chimney, up which air rushes so rapidly and in such volumes as to form the great outwelling, cauliflower thunderheads.

Presently rain forms in the towering cloud and cools the lower air through which it falls, largely by evaporation. This cooled air in turn, increasing in density, as it is chilled, drops to lower and lower levels and soon quite to the earth, where it rushes forward as the dust-raising gale that just precedes the rain. The outrushing cooler air underruns and buoys up the warm humid air in front of it—starts upward this feeder and maintaining support of the storm.

The cooler air that comes down with the rain rushes forward on the ground and stays down. The warmer air that is pushed up enters the forward portion of the storm, furnishes the rain and stays up.

Now, the rapid uprush of the warm air from which the cloud and rain are condensed causes another thing of interest, namely, the production of hail, and it comes about this way: Since no raindrop can fall through still air faster than about twenty-five feet per second, nor the smaller ones nearly that fast, it is clear that the uprushing air within the thunderstorm cloud carries much rain to great heights where, in many cases, some of it is frozen. But the rising air is fitful and puffy, so that the frozen drops fall back again to lower levels where they pick up a coating of water. Many of them fall on down and are melted on the way. Others, however, are caught in another rising blast and again hurled back to the freezing levels where a further coating is gathered. In this way, many of the stones are carried back and forth between realm of snow and region of rain, until, with shell after shell of clear ice and opal snow, they have grown so large and heavy that the uprushing air no longer can support them, and they fall to the earth as hailstones; generally no larger than ordinary marbles, but on rare occasions as big as baseballs and decidedly dangerous. The torrential precipitation of the thunderstom and its rain gushes are caused by the rapid and fitful uprush of the sustaining humid air.

There still is another feature of the thunderstorm, the very thing that makes it a thunderstorm, the lightning, that is caused by the uprush of air in the midst of the cumulus cloud. As the raindrops are driven up and whirled about by the convectional winds within the cloud they over and over are united into larger drops and again broken asunder, while with every rupture tiny droplets are torn off and carried on to still higher levels. But this is not all. As Simpson, the present director of the British Meteorological Office, has demonstrated, the breaking or rupturing of the drops is also an electrifying process. The larger drops become in this way positively charged and the spray negatively charged. Furthermore, the larger drops with their positive charges accumulate, because they are relatively heavy, in the lower portion of the cloud, while the negatively charged spray, because it is lighter, is blown to the upper portion. As these charges grow, the tendency to discharge—for the opposite charges to unite—increases until at last the spark or lightning, as we call it, passes; generally between the upper and lower levels of the same cloud, and less frequently to the earth.

The lightning usually lasts only a small fraction of a second, and often is flickering, owing to a series of separate discharges following each other in quick succession along the same path.

The duration of the flow of the current is very short, but its volume, while it lasts, is amazingly great, even tens of thousands of amperes. Its path through the air often is several miles long, devious and frequently branched at the sharper turns, but very slender. We do not know how slender, but there is reason to believe that even the most violent discharges may be no thicker than a lead pencil.

The discharge suddenly heats the air through which it passes to an unknown but very high temperature, and also tremendously ionizes it, that is, in a sense, smashes to pieces its very atoms. Thus a violent explosion, or outblow of the air, is produced all along the path of the discharge. It is this explosion that starts the sound waves we call thunder.

A great deal more might of course be said about the thunderstorm and its phenomena, for the subject is a big, interesting and important one; but this is enough, perhaps, to assure us it was no idle boast of the giant cumulus when it averred:

> I wield the flail of the lashing hail,
>   And whiten the green plains under,
> And then again I dissolve it in rain,
>   And laugh as I pass in thunder.

INSECT SOCIOLOGY

By Dr. VERNON KELLOGG
THE NATIONAL RESEARCH COUNCIL

The human sluggard is told to go to the ant to learn industry. The human sociologist might be told to go to the ant to learn sociology, for the ants have carried one form of social life to a degree not yet nearly approached by any group of human beings. This is that form called communism. Perhaps we can learn from the ants whether we ever want to go as far as they have in the way of communism.

Ants are insects, but not all insects live social or communal lives. Most of them live solitary and independently as individuals, although they may be crowded together in enormous numbers. Some entomologists attempted to estimate the number of plant lice living on one little cherry tree. He made it, in round figures, about 12,000,000. But these plant lice were not social; they were just so many individuals crowded together but having no special relations to each other. Some of *us* are inclined to live that way.

There is a beautiful large red-brown butterfly, called the monarch, which is spread all over this country. These butterflies live most of their lives as quite independent individuals, having nothing

to do with each other except at mating time. But they show a certain beginning social life, for sometimes tens of thousands of them come together, because of some gregarious instinct, although for what purpose we do not know. I have seen such gatherings in California where, in a few pine trees on the shore of Monterey Bay, there would be thousands of these butterflies, clinging to the branches and to each other, so as to form beautiful, living festoons, hanging from the trees.

There are certain small mining bees, each female of which makes a little nest burrow in a claybank in which it lays an egg and places a store of food for the young which is to hatch from this egg. But a few kinds of these bees have developed the interesting habit of having several mother bees combine to dig a common main burrow, off from which each mother makes a private short side burrow for her own egg and food; a sort of first step toward apartment house social life.

Then come the bumblebees, all the species of which live in family communities in rough nests underground, with three kinds of individuals or castes making up the family; a queen, which is the mother of the whole community, some males, which are drones, doing no work, and a large number of workers which are females, incapable, however, of laying eggs. The community is started by a queen or egg-laying female which has passed the winter in solitary hiding under a stone or in a crevice in the ground, and which comes out in the spring, hunts a place for a nest, gathers a little mass of flower pollen and nectar and lays a few eggs on it, from which hatch only workers. These workers enlarge the nest and bring more food, while the queen stays at home and lays more eggs. This process is repeated several times, until late in the summer a brood is hatched in which are males and new queens as well as workers. Then the males and new queens leave the nest, and the workers begin to die. Later the males die, and only a few queens are left to go into hiding for the winter and come out in the next spring to found new families.

The social wasps, such as the yellow jackets and hornets, have the same kind of a social life history as the bumblebees, only their nests are usually made above ground of wood-pulp paper fastened under eaves or attached to the branch of a tree. But both bumblebee and social wasp communities break down each year.

Not so with the honey-bees. Their communities go on continuously, only part of the workers dying in the fall, and enough pollen and nectar being stored up in the autumn to provide the community with plenty of food through the winter. The queen may live for four or five years, new queens being produced occasionally,

each to start a new community by going out of the hive with a swarm of workers, thus providing the beekeeper with the nucleus for a new hive.

In a honey-bee community the different kinds of necessary work, such as food-gathering, wax-making, cell-building, nursing the young bees, cleaning and ventilating and guarding the hive, etc., are done by different groups of workers. There is a division of labor among them, which is exactly what forms the basis of human social life.

When we come to the ants we find many varying degrees of communism for, unlike the bees and wasps, many kinds of which live strictly solitary or independent lives, all the different kinds of ants—and we know more than 3,000 of them—maintain some form of communal life. The communities of some are small, with only a few dozens of individuals in them, while some are very large, with hundreds of thousands of members. There are often, also, several kinds of individuals among these members, not only queens, drones and workers, as with the bees and wasps, but also soldiers and different sizes of workers. And each kind has its own particular function to perform in the community.

Ants, like human beings, have different ways of getting a living. Some are hunters, capturing and killing other insects; some are agricultural, collecting and storing seeds for food; some are predatory robbers, carrying off the stored food of others. Some have adopted a kind of dairying habit, taking care of herds of plant-lice, the "ant-cattle," from which they get honey-dew, which has been called the national dish of the ants. Some are slave-makers, depending on slave ants to take care of their young and do all the work of the community. Two different kinds may also live together as messmates; or as hosts and parasites.

Now with all the ants and with those kinds of bees and wasps which have adopted a communal life, there is an entire giving up of the life of the individual for the life of the community. Each worker ant or bee or wasp works not for itself but for the community. The worker collects food not for itself but for everybody. It has no children of its own; but it helps take care of the children of the community, which are all produced by the queens. Biologically, the communal insects are very successful. Their communities thrive; their species persist and increase. They live in all the lands of the earth except in extreme arctic and antarctic regions, and on the summits of lofty mountains, and their numbers probably exceed those of all other insects. They have been called the most successful of insect kinds. But are they happy? Nobody knows.

THE CONSTRUCTION OF MEASURING INSTRUMENTS IN THE FIELD OF EDUCATION

By Dr. S. A. COURTIS

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THE development of a science of education is no isolated phenomenon. It has a history as well as a background. In my opinion the significance of present-day achievements in the development of educational measuring instruments, and the correct interpretation to be placed upon the period of educational experimentation through which we are now passing, are both to be derived from a consideration of what has taken place in other sciences.

I am going to attempt to present three distinct, but related, sets of ideas. First, with the aid of historical analogies, I shall endeavor to interpret the present status of education as a science; second, I shall review significant aspects of the existing techniques of test and scale construction; and, third, I shall discuss certain aspects of the difficulties met in making use of measurement in the field of education. In covering so wide a range of ideas I shall be in danger of making statements too broad, generalizations too far-reaching. For all such lapses from scientific precision I apologize in advance; my purpose is to sketch in broad outlines a picture that too much elaboration of detail would mar.

I. THE PRESENT STATUS OF EDUCATION AS A SCIENCE

If we review the story of man's progress in the control of natural forces, we find that through many centuries the rate of increase in control was very slow, indeed. However, there came a time when the technique of inductive experimentation was clearly formulated and ably demonstrated. Ever since that day all who have desired to do so have been able to pursue the search for truth in a manner that is certain to secure substantial rewards.

There is no need for me to remind you of what happened; of how the new method spread from one field to another. In each field to which it has been applied it has invariably transformed the existing concepts and explanations from a speculative to an experimental basis. The diagram presents the essential elements of the evolution of science in a manner which will enable you to

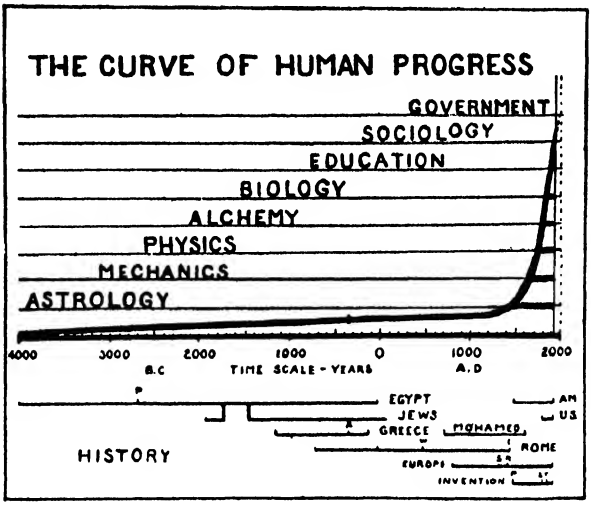


FIG. 1. The curve in the figure is drawn to represent the rate of growth of human control over the forces of nature during the last six thousand years of human history. The period of rapid growth began with the clear formulative and effective use of the inductive method about 1200 A. D. The use of the method in connection with the method of logical deduction developed during the previous centuries has spread from one field of activity to another. For comparison the duration of various nations and countries is shown below. P = building of pyramids, A = Aristotle, W. E. fall of Roman empire in West and East, S = scholasticism, R = renaissance, P = printing, S = steam engine, T = telephone.

get easily the first point I wish to make, that present-day attempts to study educational problems scientifically are but, the inevitable outcomes of the spread of scientific methods from the first fields of inquiry in which they were developed. Man has at last begun to apply to himself that technique of investigation which has proved so effective in all other fields. He has at last begun to use on himself the one means by which it is possible to differentiate between ideas which are merely products of imagination and those which are in accord with nature's immutable laws.

It is reasonable to suppose, is it not, that the course of development of a science of education will closely parallel the development of sciences in other fields. There are regular cycles in such development. For instance, the primitive stage is what may be called "general" observation, such as is possible with the unaided eye or with simple counting or measuring. A "common-sense" explanation soon follows: an explanation, however, which usually contains many imaginative and mystical elements. If we use the field of astronomy for an illustration, the common-sense explana-

tion is that the sun, moon and stars revolve around the earth, and the imaginative and mystical elements are all the weird beliefs and practices associated with that oldest of the pseudo-sciences, astrology. Any theory, however, has this virtue; it stimulates further observation. Eventually discrepancies and difficulties are discovered which in time give rise to new concepts and to a rival theory. Then a conflict begins. In such a situation it is recognized that the truth of either theory can be established only by the aid of more complete and more precise data. Measuring instruments are invented, recourse is had to experimentation and a transition period ensues, characterized by a chaos of conflicting hypotheses and by the rapid accumulation of a rich fund of data. In the fulness of time, a man of genius arises, a new synthesis takes place, new generalizations are made, laws are formulated and order is restored. The invention of measuring instruments and a feverish period of experimentation under conflicting theories are the outward signs of a transition phase.

An interesting aspect of the process is the length of time it takes to change from the old to the new. Counting from the first publication of his ideas by Copernicus in 1529[1] to the publication of the Rudolphine Tables by Kepler in 1627 the period for astronomy was almost exactly a century. Even from the beginning of the construction of better instruments of observation by Tycho Brahe to the formulation of the great generalizations of Kepler was 33 years (1576–1609). The total time of the transition period from the announcement of the new theory by Copernicus to its complete proof by Newton through the formulation of the law of gravitation was a century and a half.

If we turn to another field the various phases of the process take approximately an equal interval of time. Thus, from the publication of Boyle's "Sceptical Chemist" in 1661, with its appeal to the balance and to experimentation, to the formulation of the atomic theory in 1804 was also approximately a century and a half. The first century of this period was devoted to the development of instruments and techniques of measurement. It ended with the development of the new concepts of elements, mixtures and compounds to replace the "fire, water, earth and air" of the ancients, but it required another full generation (34 years) of measurement, experimentation and discovery before the harmonizing generalization of the atomic theory was reached.

More pertinent to our interests to-night, perhaps, are the figures in regard to the development of instruments for measuring tem-

[1] This and the following dates are taken chiefly from Sedgwick and Tyler's "Short History of Science" and from the Encyclopedia Britannica.

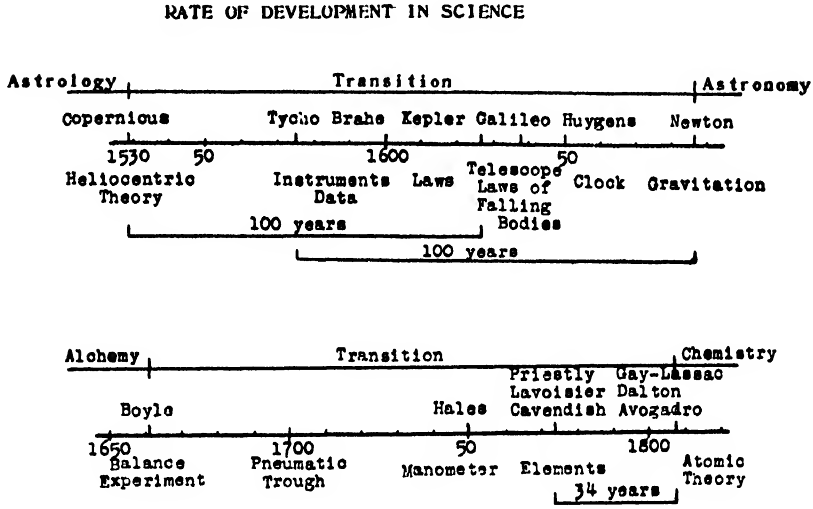


FIG. 2. The figure shows a time scale for two periods of transition, the first from astrology to astronomy, the second from alchemy to chemistry, each approximately 150 years. Men are given above the time scale and events below. These periods are characterized by the invention and perfection of measuring instruments and the rapid accumulation of data.

perature. Galileo gave the world a crude air thermometer in 1597, but it took more than a century (117 years) before the improvements that were gradually made culminated in Fahrenheit's mercury thermometer. This instrument, which was so satisfactory that it has continued in use until the present day, is of special interest to measurement men in education; for it is a scale without a true zero point, like most of the educational scales. Yet it has proved to be of very great service. In spite of its serviceableness, it is important to note that 63 years passed before Charles was able to announce the law for volume and temperature in gases. Yet Boyle as early as 1661 had determined the relation between pressure and volume in gases at constant temperature. The law of Charles made possible the concept of absolute temperature, but this generalization was not given to the world by Lord Kelvin (1862) until another 75 years had passed.

Instances such as these might be shown from many sciences. In general, it would seem that it has taken at least three generations (100 years) from the time a new master theory has been announced before measuring instruments have been invented and scientific experimentation begun; also it has taken on the average at least one and usually two generations after the invention of measuring instruments before important generalizations in the form of laws have begun to appear.

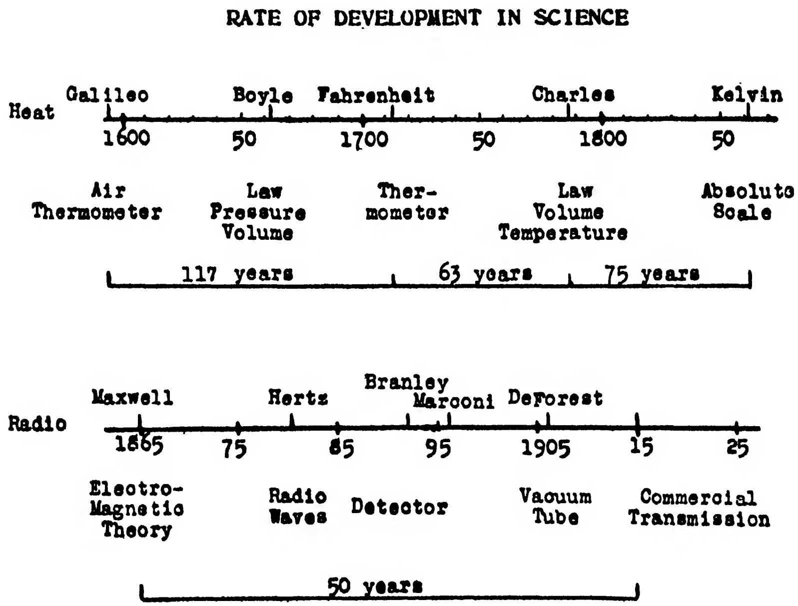


Fig. 3. The figure shows a time scale for the development and perfection of measuring instruments for heat and another for the important developments in radio. The plan of the figure is the same as that of Fig. 2.

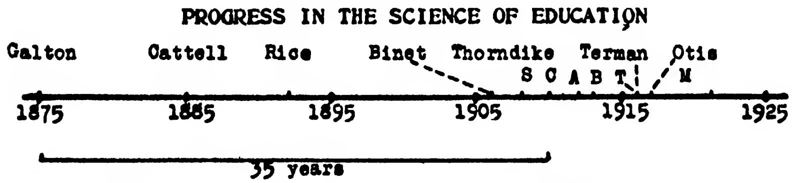
Each new science inherits a growing mass of knowledge and technique, much of which it should be able to transfer to its own field, thus greatly shortening the period needed for its development. Also in our day the means of communication are so perfected that new discoveries are immediately made available the world around. This, too, should shorten the developmental period. On the other hand, it may be well to remember that the fields most susceptible of analysis were the first ones in which discoveries were made. Even in our own day, sixty years have passed since Maxwell announced his electromagnetic theory, but we have not yet reached the end of the period of resultant rapid growth.

The science of education rests on the theory that the growth of man and the development of mind and spirit are natural phenomena, taking place in accordance with discoverable natural law. The conflicting theory, still held by many, is that the growth, thoughts and feelings of man are expressions of a spiritual entity and of forces which transcend natural law. It would seem that we are in the early stages of what has been termed previously a transition period, characterized by the multiplication of measuring devices and the accumulation of experimental data.

The end of the primitive period is placed by many at 1875, when Galton in England, Wundt in Germany and many others began to organize systematic, experimental study of human behavior. In this country Cattell in 1885 was giving psychological tests similar in purpose and content to some of the intelligence tests used to-day. In 1892 Rice was testing school systems on the comparative basis. In 1906 Binet (in France) developed individual intelligence testing; Stone in 1908 improved on Rice's work by standardizing the examination, but it was not until 1910 that the first true measuring instrument was published—the Thorndike Handwriting Scale.

From 1875 to 1910 is but thirty-five years, a relatively short period as such periods of development go. Other tests and techniques soon appeared. I, myself, developed units on the basis of objective criteria in 1910. Ayres (1912) made use of the variability of the distribution in scaling samples of handwriting. Buckingham (1913), Trabue (1916), and McCall (1921) introduced other applications and refinements. Terman in 1916 improved upon the work of Binet, and Otis in 1917 developed group intelligence testing. In recent years both educational and intelligence tests have been used literally by the million. To-day teachers everywhere are becoming accustomed to the impersonal, objective point of view, and experimentation of many types and kinds is rapidly yielding a large mass of conflicting and undigested data.

Reasoning by analogy, the next forward step will be the slow emergence of new conceptions of the fundamental factors with



Year	Man	Contribution
1875	Galton	Experimental Study of Human Behavior
1885	Cattell	Psychological Testing
1892	Rice	Comparative Testing
1906	Binet	Individual Intelligence Tests
1908	Stone	Standardized Examination
1910	Thorndike	Development of Units on Basis of Judgments
1910	Courtis	Development of Units on Basis of Objective Criteria
1912	Ayres	Development of Unit on Basis of Distribution
1913	Buckingham	New Application of Scaling Procedure
1916	Trabue	New Application of Scaling Procedure
1916	Terman	Refinement of Individual Intelligence Testing
1917	Otis	Group Intelligence Tests
1921	McCall	Refinement of Units Derived from Distributions

FIG. 4. The development of education as a science is shown on a basis comparable with that of the two previous figures.

which education has to deal and the invention of methods of measuring their effects in terms of objective units. The new concepts are already dimly outlined, but it may be expected that the exact definition, precise measurement and generalization in the form of laws will require at least one and probably two generations from the time of the invention of the first measuring instruments. That is, the transition period is not likely to end much before 1975 (1910 + 65) but an important forward step in the development of new analytical procedures and the clarification of conceptual ideas should be achieved by 1945 (1910 + 35). Possibly one of the younger men in this audience is destined to be the genius who is to make this great contribution.

In this connection a quotation from a work published in 1569 by Petrus Ramus, a French mathematician and philosopher, may not be out of place. He expressed the hope that "some distinguished German philosopher would arise and found a new astronomy on careful observation by means of logic and mathematics, discarding all the notions of the ancients."

It seems to me that we who are interested in the science of education have reason to be proud of the progress already made. The conflicting theories have been clearly defined, instruments of measurement have been invented, and important data are accumulating rapidly. What we need to do now is to welcome each new idea, each new lead, and follow it experimentally until we have determined the worth of the contribution it has to make. Above all, we should feel under obligation to make the results of experimentation available to others. We can not tell from what stimulus the new ideas may come. The need of the hour is for originality, fertility of invention, new points of view, and, above all else, that true scientific spirit which welcomes all, but accepts nothing except on the basis of valid evidence. We must scrutinize every assumption, every technique and, more rigidly than ever before, follow only where the facts lead.

II. Significant Aspects of the Technique of Test and Scale Construction

In a brief address of this sort, I can not hope to give any adequate account of the methods by which tests and scales are made, but it should be possible to outline certain fundamental procedures which are essential to an understanding of the difficulties in which the science of education finds itself at the present time.

I have chosen four methods for discussion:

Method	*Product*
(1) The "stunt" or exercise method	Examinations
(2) The recognition of difference method	Product scales
(3) The variability unit method	Performance scales
(4) The objective specification method	Rate tests

The "stunt" or exercise method is that method of test construction in which one selects a number of items similar in nature in terms of some general category and involving a desirable mental activity.

GENERAL SCIENCE TEST

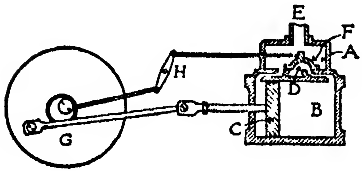


FIGURE 9

In this drawing of a steam engine:

a The fly wheel is marked by the letter . . . .
b The piston is marked by the letter . . .
c The steam chest is marked by the letter . . .
d The cylinder is marked by the letter . . .
e The sliding valve is marked by the letter . . . .

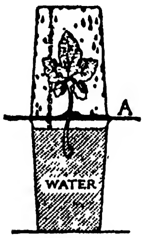


FIGURE 17

a This diagram illustrates the giving off of..................... *a*
by the leaves of plants.
b This process is called...... ... . *b*
c The rate of this process in the living plant is partly controlled by the action of the................found in the.................. *c*
of leaves.

FIG. 5. Illustration of test composed of carefully selected items each of which is really a small test in itself so that the score as a whole is merely an index of a complex of abilities instead of an expression of magnitude of a single unitary quantity.

I have chosen as an illustration an excellently prepared test of knowledge in which the defined category is general science. A test of this type has many uses and is of great service to many different types of educational workers. Yet measurements with such a test differ fundamentally from the type of measurements which are essential to the reduction of data to general laws. For instance, each item differs in content from each other item and the resulting score is only an index of general efficiency in the field covered by the test. The point I want to make is that such tests—and very many of our tests are of this character—are not true measuring instruments in the sense that they do not measure a single factor in terms of unit amounts of that factor. A score of twenty-five correct

answers in this test does not mean twenty-five units of anything. It is merely an index of the amount of an unanalyzed complex. In reality each separate item is a test in itself, but a test whose value in terms of a single unitary factor is unknown. We standardize scores from such tests in terms of grades or ages, we use them to measure rates of growth, the behavior of pupils, the relative efficiency of different methods of teaching; but all such measurements fall short of being true measurements in two particulars:

(1) The quantity measured is not unitary in character, and

(2) Any unit of amount is not equal to any other unit.

The physicist who measures length measures a magnitude of single specific characters, and any one inch of length is exactly replaceable by any other. The exercise method of test construction, in proportion to the care and attention given to the selection of content, yields valuable instruments for more precise description than is possible without them. But all measurements made with such tests are in terms of magnitudes which can not be used in the determination of law. The factors measured are overlapping complexes, and the magnitudes are not additive.

The Thorndike Handwriting Scale,[2] however, is a true measuring instrument, although by no means a perfect one. The thing measured is a simple unitary quality, "merit" in handwriting, and each unit is equal to each other unit, within the limits of the definition of unit adopted. The Thorndike scale is an educational "ruler" for measuring merit in handwriting. The merit of any new sample is determined by comparing it directly with the merit of the samples of known value which compose the scale.

In determining the value of the samples in the scale, use is made of the equal difference theorem formulated by Fullerton and Cattell.[3] The first step is to define a unit difference in merit. Two samples are taken as differing one unit in merit when, of a group of competent judges, 75 per cent. agree that one is better than the other. If a large number of samples ranging from poor to good are compared with each other by a sufficiently large group of judges, a series of samples may be selected each of which is recognized as better than the one below it by 75 per cent. of the judges. Thus in the figure "A" is one unit better than "B" and "B" is one unit better than "C," because in each case the difference is recognized by 75 per cent. of the judges. Samples A, B and C form a section of a scale, each element of which differs from the element below it by a unit amount. It only remains to determine how far the poorest

[2] *Teachers College Record,* March, 1910.

[3] "On the perception of small differences," University of Pennsylvania Press, Philadelphia, 1892.

RECOGNITION OF DIFFERENCE METHOD

Differences equally often recognized are equal, unless always or never recognized.

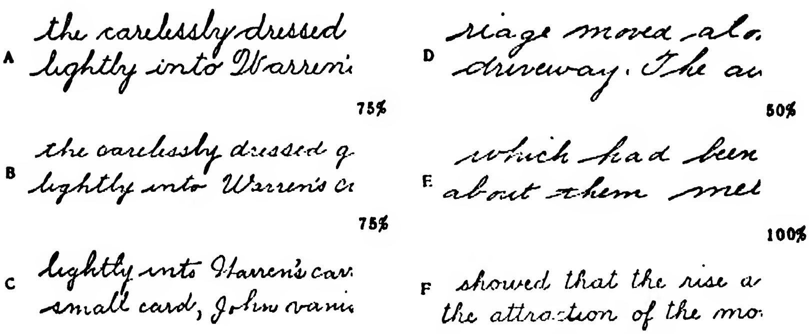


FIG. 6. Portions of samples from the Thorndike Handwriting Scale. Sample A is as much better in merit than B as B is than C, because the differences are equally often recognized. (Each difference is recognized by 75 per cent. of the judges.) Samples D and E are equal because the judgments divide 50–50. In the case of E and F, however, while F is better than E, it is impossible to tell how many units better because the difference exceeds the limits of doubtful discrimination.

sample is above zero writing, or writing of no merit, to fix the value of each element of the scale.

If two samples of equal merit are compared (as D and E) 50 per cent. of the judges will say one is better and 50 per cent. that the other is better. On the other hand, if the differences between the two samples exceed the limit of doubtful discrimination, 100 per cent. of the judges will recognize the difference, no matter how much beyond the critical amount the difference in merit may be. That is, between the limits listed in the theorem "always noticed" (100 per cent.) and "never noticed" (50 per cent.), it is possible to change percentages of "better than" judgments into units of amount. In the figure four diagrams are shown. The first (50–50 per cent.) represents the judgment results when the samples are equal, the second (67–33 per cent.) when the samples differ by half a unit, the third (75–25 per cent.) when the difference is one unit and the fourth (91–9 per cent.) when the difference is two units. Notice that a normal surface of frequency is assumed and the 75–25 distance from the mean along the base line is used as a measuring rod. The percentages of the normal surface of frequency corresponding to each unit, or fraction of a unit, along the base line are readily computed.

The actual process of selecting and evaluating samples followed by Professor Thorndike and others who have constructed scales by

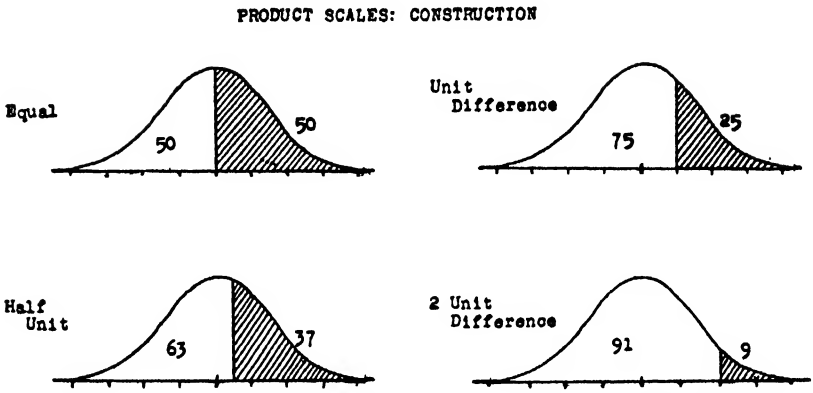


FIG. 7. Illustrations of the relation between the percentages of "better than" judgments and the division of the base line into units. White = "better than" judgments; shaded = "worse than" judgments for one sample. The distance from the mean to the shaded portion in the figure representing 75–25 is taken as the unit.

this technique was much more complex than that described, but enough has been said to indicate a general process of evaluation which yields measures of amount in terms of equal units. The resulting scale thus satisfies the two criteria given for a true scale, the unitary character of the quantity measured and equality of units of amount.

However, there is experimental evidence that while the units are equal in the sense of being equally often recognized, they differ in their absolute values.[4] This is in accord with the Weber-Fechner law as quoted by James,[5] that sensations are proportional to the logarithms of the stimuli which cause them. Equal difference units, being based on sensations, are units of varying absolute magnitude. In the figure equal difference units are shown along the base line, while the perpendiculars represent the corresponding absolute magnitude, in terms of the Weber-Fechner law, of the sensations necessary to produce them. The difference between the curve and the base line shows graphically the difference between geometric and linear scales. It is not known whether the handwriting units follow an exact logarithmic law or not, but it is certain that the relation is of this general character. Consequently, one of the problems of measurement with such scales is to determine the exact relation which holds between such units and to use the mathematical procedures appropriate for units of varying absolute magnitude.

[4] Unpublished paper presented before Section Q at a previous meeting.

[5] "Psychology" (Briefer Course, 1905), page 22.

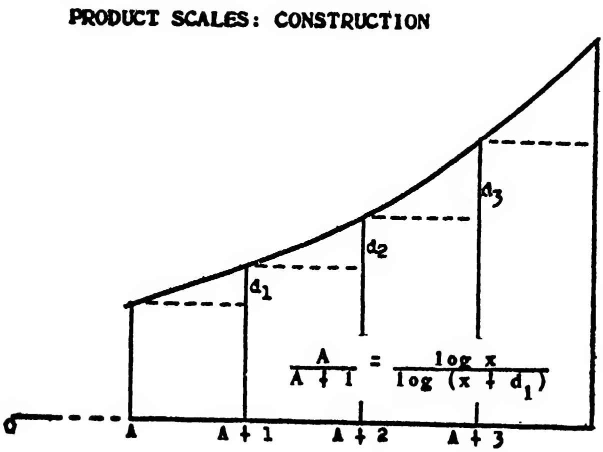


FIG. 8. Illustration of relation between equal judgment units, A to (A+1), (A+1) to (A+2), etc., (base line) and the corresponding true absolute values of the sensations upon which the judgments are based (perpendiculars) if judgment units follow the Weber-Fechner law.

A second problem is the determination of the best methods of locating the zero point, a problem too complex to be more than mentioned at this time.

A third problem has to do with the determination of the competency of the judges. It has been shown experimentally that the absolute magnitude of judgment units is a function of the degree of discrimination of the judges.[6]

These difficulties do not destroy the value of the scale as a measuring instrument, but they make it more difficult to correctly interpret the results secured. Nevertheless, it is now possible to measure the personal errors of those who use the scale, to determine easily the quality of any sample within 2 per cent., and to reduce this error any desired amount by giving sufficient time and care to the procedure followed in constructing and using such scales.

The second method of constructing true measuring instruments is the variability unit method. Fundamentally, it is an extension of the principles underlying the recognition of difference method. In this case, however, the units are not based on *recognition* of differences, but upon differences in performances caused by differences in difficulty. This is the reason tests so constructed are called performance scales.

For illustration I have chosen a few words in spelling from the spelling performance scale evaluated by Buckingham.

[6] "The effect of competency in judges upon the size of the unit in judgment scales," *School and Society*, Vol. XVIII, No. 446, July 14, 1923.

VARIABILITY UNIT METHOD

	Words	Percentage Failing	Percentile Value
1.	______	0	0
2.	Only	11	30
3.	Forty	35	44
4.	Saucer	58	53
5.	Too	73	60
6.	______	100	100

Position on Scale

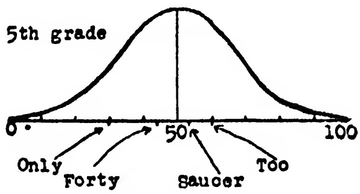


FIG. 9. Illustration of a performance scale in spelling and of the location of the elements of the scale on the base line of a hypothetical distribution by the "percentage failing" method.

The words "only," "forty," "saucer," "too," constitute a scale for the measurement of a simple unitary type of performance, spelling, because if difficulty in spelling is defined as that quality of a word which determines the frequency with which any homogeneous group of children misspell it, "too" is more difficult than "only." "Too" is misspelled by 73 per cent. of fifth grade children, while "only" is misspelled by but 11 per cent. of the same children.

The degree of difficulty of a word is determined by its position on the base line of a surface of frequency, distance from the mean being measured in terms of variability. That is, spelling ability is assumed to be distributed normally, and the mid-point of the distribution is taken as 50 units. If now the further assumptions are made that (1) the base of distribution is cut off at certain points (ordinarily at three times the sigma distance above and below the mean), that (2) a word so easy that no fifth grade child misses it has zero degree of difficulty, and that (3) a word so difficult that every fifth grade child misses it has 100 degrees of difficulty, zero being located at one end of the base line and 100 at the other, then points on the base line may be found corresponding to the percents of children missing various words. In one illustration, "only," missed by 11 per cent. of the children, falls at 30 degrees of difficulty and "too," missed by 73 per cent. of the children, has a difficulty value of 60. Thus "too" is twice as difficult for these fifth grade children to spell as "only" in terms of defined units.

It may be questioned whether the assumptions made are warranted or not. The answer is that at present we do not know. There is, of course, some evidence in support of each assumption, but there is other evidence which is in conflict with the first. Furthermore,

certain points have not yet been thoroughly investigated. Such scales are undoubtedly less perfect than they will ultimately be, but that is not the point. The important matter for the present discussion is that the variability unit method provides for evaluating difficulty of performance in a constant manner. Measurement with such performance scales enables the scientist in education to gather objective data from which he can not only describe educational phenomena more precisely than before, but also test the validity of the assumptions on which the construction of the measuring instruments is based. Such experimentation inevitably leads to the improvement of the technique of construction.

There are three important problems which must be solved before performance scales can be perfected. If some other means could be found for determining the difficulty of spelling performance, it would be possible to check one series of values against the other. Objective determination of difficulty is greatly to be desired, but little progress has been made in this direction. On the other hand, certain difficulties, caused by the variation in the size of units which result from changes in the variability of the group, have been overcome by using a standard age group as the basis for the construction of all performance tests. Further improvements are easily possible and are certain to be made.

A third problem deals with the absolute value of the units. Variability units may well be of varying absolute magnitude. If so, devising a suitable mathematics for dealing with such units would be a prerequisite to the determination of ultimate educational law.

It may be well to note in passing that, theoretically, the score of a child in a spelling performance scale is not the number of words spelled correctly but the degree of difficulty of the last word spelled correctly. Thus, a fifth grade child who could spell "only" correctly but could not spell "forty," "saucer" or "too," would have a spelling ability of 30 units, while another child who could spell no words of greater difficulty than "too" would have a spelling ability of 60 units. Performance scales are used to measure the degree of development of ability. They are essentially classification tests.

The third method of test construction that will be discussed is the objective specification method. The units under such a method of construction are all equal, since each in terms of specifications is made to be just like the rest. The thing described in the specifications, however, is not judgment or performance or any function of ability, but the objective characteristics of the materials (subject-matter) with which the performance being measured deals. Equal-

ity of units in such tests, therefore, is based upon equal amounts of work. In doing work, time is always a factor. Accordingly, performance is measured by the amount of work done per unit of time and such tests are called rate tests. They tell nothing whatever about development of ability, but they do reveal the degree of skill exerted in the control of ability at a given level. Scores in rate tests reflect every change in any of the factors which cause or condition performance and must be corrected to standard conditions before they are comparable.

Scores in all rate tests have two dimensions, rate and quality or accuracy. Skill is never measured accurately by either rate or quality of performance alone, but by a score which is a function of both rate and accuracy.

DETROIT PUBLIC SCHOOLS

TEACHERS COLLEGE

Test 1. Addition — Standard

Instructions. When the examiner says "Start," work as many of the examples below as you can in the time allowed, but be sure you get the right answers. Do not hurry but work as rapidly and steadily as you can work correctly.

Each time the examiner says "Mark," draw a line around the example on which you are then working, go to the next. Do not finish an example after drawing a circle around it.

17	59	71	28	37	36	14	23
86	84	93	39	45	41	76	31
97	13	17	76	12	46	22	68
88	46	71	11	64	95	99	96
25	85	33	57	78	56	56	47
65	22	64	88	91	81	31	53

45	12	44	36	83	15	69	67
23	31	97	85	18	48	30	99
87	85	59	64	41	39	36	21
71	46	36	97	94	77	69	42
76	93	69	22	38	96	98	84
91	34	54	55	58	59	52	72

FIG. 10. Illustration of a rate test prepared by the objective specification method. See next figure.

The rate test chosen for illustration of the objective specification method of construction is an addition rate test. The specifications under which it was constructed are that each element or unit must (approximately) consist of

(1) Six two place numbers.

(2) Have 350 ± 50 as an answer.

(3) Contain two easy, six average and three hard combinations, defined as below.
(4) Contain not more than two pair of combinations whose sum is ten.
(5) Contain not more than one partial sum ending in zero.

OBJECTIVE SPECIFICATION METHOD

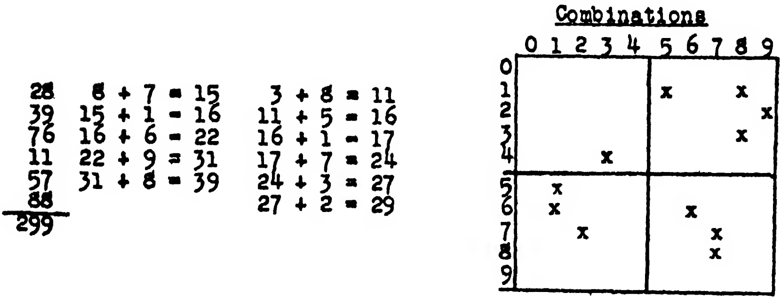


FIG. 11. Illustration of method of preparing each example shown in Fig. 10. The separate additions involved in the example are shown; also the analysis of these combinations as to their position. Each × represents a combination. 1 + 5 is indicated by the × immediately under 5.

To construct an example the 100 fundamental addition combinations are first divided into groups or classes (in this case three, "easy," "average" and "hard") by cross lines. These classes may be made as exact as desired. The illustration chosen represents a coarse grouping that defects caused by the coarseness may be evident. In the diagram one element of a combination is represented by the vertical axis and the other by the horizontal axis. Thus $\genfrac{}{}{0pt}{}{3}{4}$ is represented by a cross in the row marked by four at the left and in the column under three (4 + 3) and for the purposes of this test is classed as an easy combination.

The second step is to build up, combination by combination, a six two-place number example. In all partial sums of 10 or more the ten's figure is disregarded and the combination is classified on the unit figures. Thus 16 + 6 is classified as 6 + 6, a hard combination, as it falls in the fourth division. Much patience and skill may be required in selecting and organizing combinations to make the resulting example conform even approximately to the specifications, especially if the specifications are very complex. Note that in the illustration given the sum is just outside the limit set by the specifications and the number of combinations of the various types is one "easy," seven "average" and two "hard." Nevertheless, it was included in the test as conforming *sufficiently* to the specifications for the purposes for which the test was to be used. Similar

irregularities will be found in each example. Nevertheless, the accuracy scores made by one hundred sixth grade children sufficiently skilful in addition to attempt ten or more problems in four minutes were as follows:

TABLE 1

PERCENTAGE OF RIGHT ANSWERS FOR EACH EXAMPLE FOUND IN THE PAPERS OF ONE HUNDRED SIXTH GRADE CHILDREN TAKING THE TEST UNDER STANDARD CONDITIONS AND POSSESSED OF SUFFICIENT SKILL TO DO AT LEAST TEN EXAMPLES IN FOUR MINUTES

No. 1—81 per cent.	No. 6—85 per cent.	
No. 2—79 per cent.	No. 7—89 per cent.	Mean value 83 per cent.
No. 3—85 per cent.	No. 8—81 per cent.	Mean deviation of distribution 2
No. 4—83 per cent.	No. 9—80 per cent.	
No. 5—81 per cent.	No. 10—79 per cent.	

In other words, the examples are equal, on the average, within 3 per cent. They could have been made equal within any desired limit, say one half of one per cent., by increasing the complexity of the specifications and by expending more time and care in their construction.

The objective specification method exactly reverses the method of evaluation used in the variability unit method of test construction. The latter determines the difficulty of the elements of a test from the performance of the children; the former makes the objective characteristics of the test elements equal and uses these objectively equal units to measure the behavior of children. Any change in performance, then, indicates that some change in either ability or the functioning of ability has taken place. Rate tests thus yield measures of performance in units of equal absolute objective value.

As with the other forms of test and scale construction, the objective specification method furnishes a number of unsolved problems. For one thing, the specifications on which the units are built must be adequate. They must deal with every characteristic of the subject-matter that affects the functioning of ability; otherwise the variations in value may be extreme. Thus, if the only specification was that each example should consist of six two-place numbers, the mean value of the units and the probable error of the distribution of the values would be greatly changed. For school subjects it is at present difficult to analyze subject-matter into the essential characteristics which must be controlled to make units equal.

A second problem is that of determining objectively the comparative difficulty of two rate tests. For instance, if one test is

composed of six two-place numbers and the other of nine three-place numbers, there is no known valid method of expressing the relative difficulty of the two units in terms of a single objective scale of difficulty. Indeed, except for Professor Thorndike's remarkable contribution,[7] the fundamental problem of what is meant by difficulty has received so far but very little attention from those interested in test and scale construction.

A third problem, which is common to all tests, but which is brought to light more clearly by rate tests than by other types, is that of validation. It is easy to call a test an addition test, but experiments soon prove that performance in such a test is merely the resultant of the action of a great complex of factors of which adding ability is but one. Educational science stands in great need of effective method of analysis of such complexes into unitary components which will "stay put." The situation in education closely resembles that in chemistry shortly before the discovery of oxygen and the development of the concept of elements. Every rate test measures performance only. There are those who maintain that the same is true of performance scales and of every other type of test; that the present definitions and measurements of intelligence and ability are only partially valid. I rate myself as a member of this group.

A fourth important problem is the correction of scores in rate tests to standard conditions. In handwriting it is difficult to tell whether a rate of 80 letters per minute at quality 60 Ayres is better or worse than a rate of 105 letters per minute at quality 35 Ayres until both have been reduced to either rate at standard quality or quality at standard rate. If it is found, other things being equal, that at a rate of 100 letters per minute both children write at quality 40, or that at quality 70 both children write at the rate of 70 letters per minute, it is easy to see that the children are equal in ability. At present, however, there are no valid means of making such comparisons.

Education as a science, therefore, must be judged to have taken two steps on the road to progress, but two steps only. She has glimpsed the vision of the objective impersonal determination of truth and has set her face in the right direction. She has learned how to construct crude but true measuring instruments which make possible the collection of scientific data and the raising of fundamental problems to consciousness. She is now busily engaged in taking the third step, improvement of her measuring instruments

[7] "The measurement of intelligence," *Psychological Review*, Vol. 31, No. 3, May, 1924.

and the accumulation of a mass of data. In the relatively near future she may be expected to take the fourth step, development of fundamental concepts.

III. Comparison of the Measurement Activity in the Physical and Educational Sciences

Before bringing this paper to a close, there is another phase of the situation which merits discussion. Many persons are deceived by appearances and judge that measurement in education and measurement in the physical sciences differ in kind as well as in degree. This is not so. In both, the instrumental errors are small and measurable. In both, the size of such errors is fixed by the time and effort expended in their reduction. In both, such errors have been reduced to limits adequate for effective generalization. In similar fashion, in both the personal errors of the observers are measurable and either compensating or removable by correction. In both, the objectivity of the things measured is high. A sample of handwriting or the sum in an addition test are as objective as a crystal or a flower. This point is frequently misunderstood. If a child writes, the rate of his writing can be determined to the exact number of letters written with very small instrumental and observational errors. The quality of writing can be determined easily to within one per cent. So far, there are no differences between measurements in the two fields. If, however, we examine the type of measurement used, a characteristic difference is evident at once. The method of measurement employed in the physical sciences is often direct; length is compared with length, force with force. When indirect measurement is used as in the measurement of an electric current, the complex situation which gives rise to the electric current-chemical action, electrodes, resistance, etc., is easily broken into fundamental elements, each of which is objective and may be maintained at constant conditions. Because of this constancy, the effects of the elements are additive and the swing of a galvanometric needle over a graduated scale reflects in an exact way the strength of the intangible electric current. In education, however, the complex causes which operate to produce behavior have not yet proved objectively divisible into controllable factors. For instance, it is known that performance is determined by both ability and effort, but no method has yet been discovered by which one may be controlled, while the effect of the other upon performance is determined. In other words, all measurement in education is indirect, and the apparent factors are not only many but overlapping. One psychologist has written:[8]

[8] J. A. Melrose, "Method for organic problems," *Psychological Review*, Vol. 32, No. 1, p. 74.

When Archimedes says, "Give me a place to stand and I will lift the world" his problem seems heroic because stated in heroic terms. Had he, however, tried to lift himself by his own bootstraps he would have faced the same dilemma. Psychology is in this dilemma. Its fulcrum rests upon its load.

In other words, the apparent difference between measurement in education and measurement in the physical sciences has its source, not in the differences in the technique of measurement, but in the more complex situation to which educational measurements are applied. Upon scientific analysis, educational products prove to be vastly more intricate, of vastly greater complexity, than had been supposed. The ultimate technique of analysis will have to be correspondingly more penetrating and subtle than for any science so far developed.

The measurement situation in education may be summarized by saying that the quantity actually measured is always some objective aspect of behavior in specific situations and under specific conditions. The quantity whose measurement is desired, however, is ability or general power to do; that is, power to perform, as measured under standard conditions, from which behavior in any specific situation may be predicted. Therefore, ability must always be *inferred* from behavior *and* conditions; it can never be measured directly.

In a general way the variable factors which affect the functioning of ability are known. They are:

A. External conditions; such as light, heat, materials, etc.
B. Physiological conditions of the organisms; such as vitality, fatigue, etc.
C. Ideational conditions of the organism; such as set, purpose, and the like.
D. Emotional condition of the organism; such as fear, joy, etc.

However, knowledge of these factors and their effects rests at present upon general, and in the main, subjective estimation. Progress is dependent upon the reduction of the vague general concepts of forces and factors to specific concepts built upon objectively determined evidence and precise definition.

In similar fashion it is known that the general factors determining ability are:

A. The quality of the inherited mechanism as to composition, functional relationship between its parts, and powers of growth and adaptation.
B. The maturity of the organism, or the stage of development it has attained.
C. The training which the organism has undergone, or the amount, nature, intensity, recency of the practice in performing the given functions.

Capacity, maturity and training, or heredity, development and education, are thus vague general names for three great series of factors which also must be resolved into elements having stable manifestations before there can be effective determination of natural law in the educational field.

My thesis is that education is entitled to be ranked as a science, not because she is faced with intricate problems which can be solved only by rigid application of the inductive method, but because educationalists are actively attacking the problems of analysis by scientific methods, and inventing and using scientifically constructed instruments.

In support of this thesis I shall present by way of conclusion four specific illustrations of the methods of analysis that are being developed. While none of these methods are under satisfactory control, all of them are suggestive and promising. It is safe to predict that it is along such lines of analysis that progress will eventually be made.

My first illustration is from the unpublished studies of the supervisory department of the Detroit Public Schools. The supervisor of arithmetic[9] is at present attempting to analyze arithmetical ability into its elements and to determine the relation of such elements to the development of ability in students of various levels of intelligence.

In the test will be seen four different but related problems of the conventional type. The first is called "direct" because it nar-

Detroit Public Schools — Exact Science Department

MEASUREMENT OF EFFECTS OF COMPLEXITY OF THOUGHT PROCESS

Type	Problem	Answers			
1. Direct	Jack went to the store. He bought a pencil for 5¢ and a tablet for 8¢. The tablet and the pencil cost ________ cents.	5¢ 3¢ 8¢	8¢ 5¢ 3¢	5¢ 8¢ 13¢	8¢ 3¢ 5¢
2. Inverse	Jack went to the store. He bought a tablet that cost 7¢. He gave the storekeeper 10¢. Jack received ________¢ change.	7¢ 10¢ 17¢	10¢ 3¢ 7¢	10¢ 7¢ 3¢	7¢ 3¢ 10¢
3. Conditional	Helen has 9¢. She wants to buy a doll. The doll costs 15¢. Helen must have ________¢ more to buy the doll.	15¢ 9¢ 24¢	15¢ 6¢ 9¢	24¢ 15¢ 9¢	15¢ 9¢ 6¢
4. Abstract	A tablet cost 10¢. A pencil costs 6¢. A tablet costs ________¢ more than a pencil.	10¢ 4¢ 6¢	6¢ 4¢ 10¢	10¢ 6¢ 4¢	10¢ 6¢ 16¢

FIG. 12. For explanation of problem, see text. The child responds by drawing a line around the right answer.

[9] Louis Thiele, to whom the author is indebted for permission to use the data.

rates the elements of a simple experience in the order in which they occur. The two number facts—cost of pencil and cost of tablet—are both known before the need for their sum arises. The second problem is called "inverse," because after the first element is given, the sum in the form of 10 cents is presented and the child is called upon to resolve it into two elements before the second element, the change, can be determined. In the third problem nothing really happened. The girl has some money. She desires a doll. She knows the price. The student is thus forced to initiate an imaginative activity before a solution is possible. From one point of view the problem is identical with the second and not very different from the first, but from another point of view it is much more complex than either in that it calls for the manipulation of many mental images in grasping and controlling the situation. It involves elements of initiative and power which are not present in the preceding examples.

The fourth example omits all reference to persons and experience. It is a cold, impersonal statement of facts and relationships. There are no clues of emotional value to direct the thought process. The example calls for intellectual, abstract, generalized thinking.

When such a series of problems is presented to children in the upper third grade, the first grade in which the X or brighter children (upper 20 per cent. in intelligence) make a score of 100 per cent. on the first example, a comparison between the scores made by the X and Z groups (Z = lower 20 per cent. in intelligence) reveals at once differences in their powers. If the actual accuracy

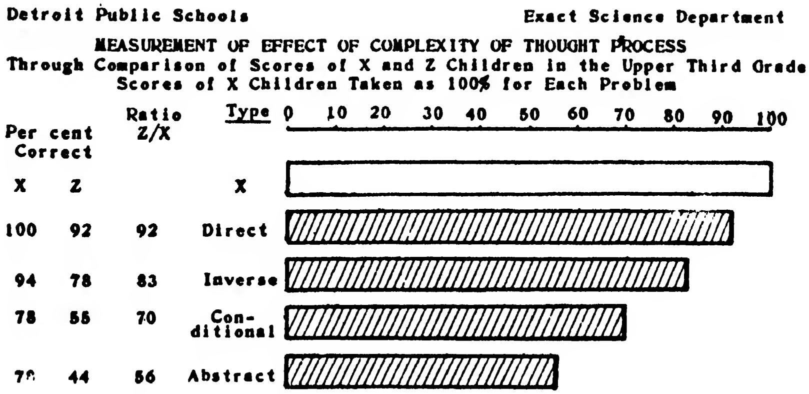


FIG. 13. The table is to be read as follows: The X children in the upper third grade made 100 per cent. on problem 1, the Z children 92 per cent., so that the Z's children's performance was 92 per cent. as efficient as the X's on problem 1. The figure indicates that the less intelligent children differ more and more from the more intelligent as the complexity of the thought process involved in the test increases,

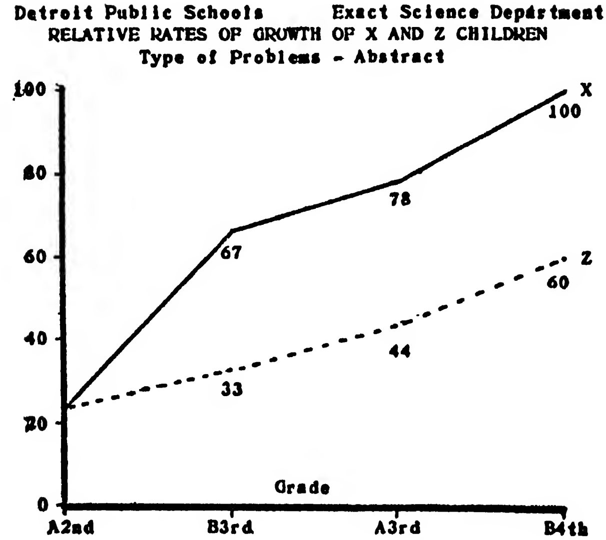


FIG. 14. The graph is to be read as follows: In the A 2nd grade the X and Z children made a score of 22 per cent. on Problem 4, the abstract example in Fig. 12. In the B 3rd grade the score of the X's was 67 per cent., of the Z's 33 per cent. The figure shows that the less intelligent children grow in mental power more slowly than the more intelligent.

scores of the X children is taken as a base (100 per cent.) for each example, the Z children perform 92 per cent. as well as the X children on the first example, but as the complexity of the thought process increases, the difference between the X and Z groups becomes larger and larger until for the abstract thinking demanded in the fourth problem the Z's are but 56 per cent. as efficient as the X's. It is possible to say, therefore, that the concept "intelligence" refers to some fundamental differences in children, much of which enables the individual to carry on abstract intellectual thought processes more readily than can be done with less intelligence.

This test may also be used to reveal another characteristic of intelligence. The lowest grade in which it can be successfully given is the upper second. In this grade the scores on the fourth or abstract problem are for both X and Z pupils below the probable score on the basis of chance alone (25 per cent.) there being but four possible ways in which the children could respond. With *one semester* of training, however, the scores of the X children (in B 3rd) change from 22 to 67 per cent., an amount of growth greater than that attained by the Z children (60 per cent.) after *a year and a half* of training (B 4th). One characteristic of intelligence

is, therefore, power to profit by experience. Under conditions of equal training, there should be an exact law expressing the relation between gain and intelligence. What that law is, however, can not be determined until more precise measures of both intelligence and ability to solve abstract problems have been developed.

My second illustration has been chosen to present a type of procedure which yields important results in the analysis of performance into ability elements. Tests 1, 3 and 5 are identical copies of a simple addition test, except that the examples in Test 1 are .25 inches apart, in Test 2 .50 inches apart and in Test 3 1.00 inches apart. Manifestly, the space between examples can not affect adding ability, so change of a single individual's score from one test to the next must be caused by the effect of the spacing. If one attempts to predict this effect, one is likely to prophesy lower scores for the more widely spaced tests. Certainly if the space between examples were increased enough (say to 100 feet), a child would be unable to complete as many examples in a given time as in Test 1. Actual trial with children, however, yields in many

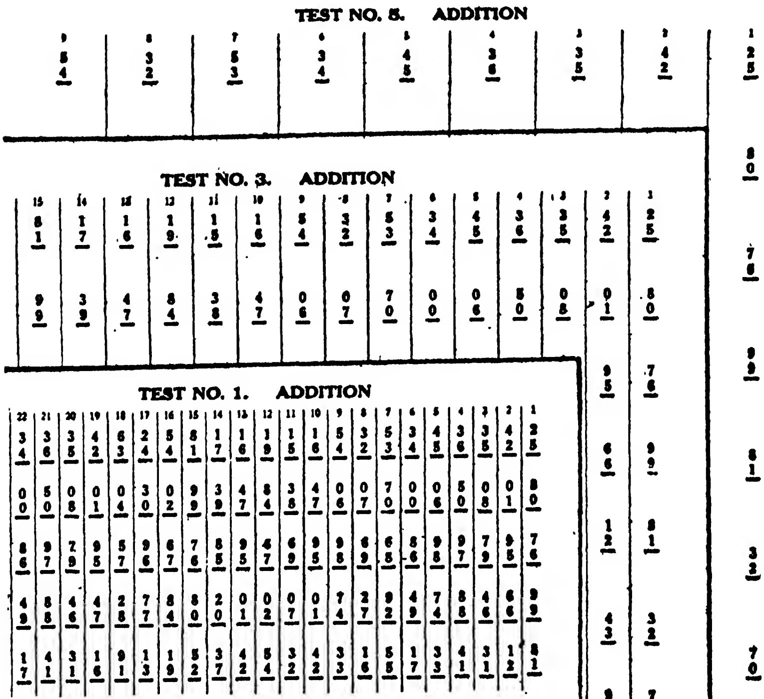


FIG. 15. Portions of three tests of the addition combinations superimposed to make comparison easy. The tests are made exactly alike except for one factor, the amount of space between the examples. In Test 1, the examples are approximately one quarter of an inch apart; in Test 2, half an inch, in Test 3, one inch.

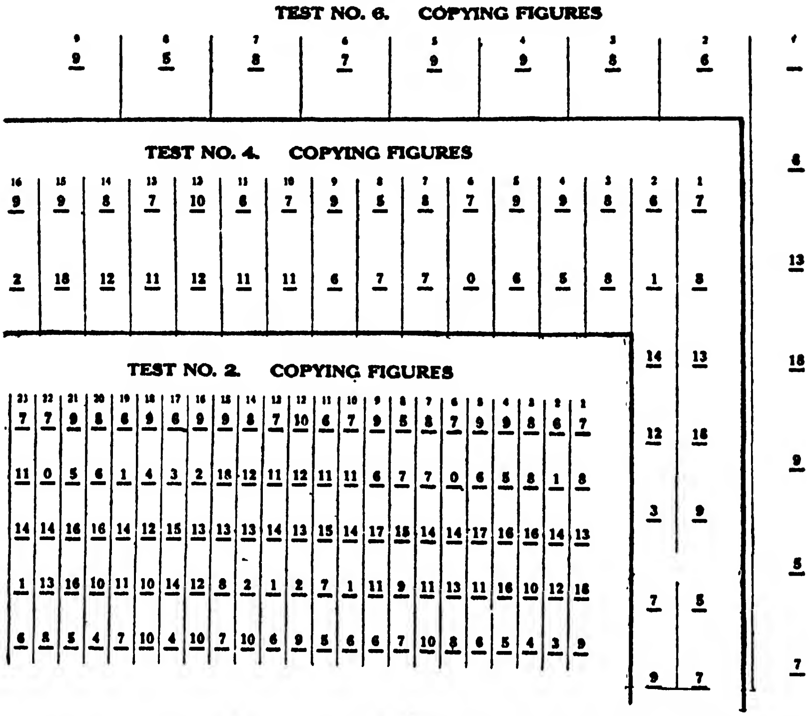


FIG. 16. Portions of three tests of copying figures made to be used with Tests 1, 3 and 5. The figures copied are the answers to the examples in Tests 1, 3 and 5. Performances in any one pair of tests are exactly the same except for one factor, adding. From the scores in a pair of tests, it is possible to derive a score for "pure" adding ability.

cases larger scores with Tests 2 and 3 than in 1. There is apparently greater freedom of movement and a stimulus to greater effort. A boy twelve years old in the seventh grade made scores (average of three trials) as follows: Test 1, 12; Test 3, 13; Test 5, 14.5; examples per minute.

Since after six years of practice in addition it is highly improbable that the boy's ability to add was changed by taking one or two brief tests, the three scores 12, 13 and 14.5 each contain as it were a constant measure, X, of ability to add combined with the effect of space, change in effort, practice effect, fatigue and similar factors. The problem, therefore, is to devise an analytical method which will enable the experimenter to extract a constant measure of adding ability from the complex scores.

The method of analysis is to construct three tests, 2, 4 and 6, similar in every particular to tests 1, 3 and 5 except in one respect, adding. Tests 2, 4 and 6 are copying tests. The numbers copied, however, are the answers to the examples in Tests 1, 3 and 5. The

outward performance in the two tests is, therefore, the same, the inward synthetic activity which produces the outward performance is also the same except that in the copying tests there is one less factor contributing to the resultant performance. The scores made by the boy previously mentioned were as follows: Test 2, 19; Test 4, 21.5; Test 6, 26. That is, for this boy the adding activity requires more time than mere perception.

For the sake of brevity I am omitting certain details of procedure necessary to standardize conditions and insure constancy of effort. It is enough to say that when the proper experimental conditions have been met, the effect of that single element in which the two tests differ may be found by dividing the product of the scores in the various pairs of tests by their differences.[10]

The result of applying this correction to the three pairs of scores obtained from this boy are 32.6, 32.9 and 32.8, results which are constant within less than 1 per cent. Unfortunately, this is a selected case. It is not possible at present to stabilize conditions for all children sufficiently to measure what might be called their "pure" adding ability, but by this method significant enough results have been secured in many fields to indicate something of its great analytical potentialities.

My third illustration will throw light upon some of the difficulties encountered in determining the effect of even such an objective and external factor as spacing through the complications of internal factors which also contribute to performance and disrupt the constancy of conditions.[11] It deals with two factors which I shall call the adjustment and the effort factors.

The figure is a graph of the scores of one individual in some twenty tests of penmanship under varying conditions and different examiners. Sometimes the members of his class were asked simply to write rapidly and well. Sometimes they were asked to write as rapidly as they could move their pens and to pay no attention to the legibility of their writing. At other times they were cautioned to do their very best and to pay no attention to their rate. At still other times various sorts of incentives were used, as money payment for improvement in both speed and accuracy, or the personal appeal of the teacher for utmost effort as a proof of their regard for her. The dotted line in the figure maps out a theoretical field of variation of performance which, it is believed, would have been obtained had the number of tests and conditions been, say, 2,000, instead of 20.

10 Correction formulae for addition tests, *Teachers College Record*: 21, Jan. 1920, p. 1–24.

11 From a series of investigations made possible by a grant from the Commonwealth Fund.

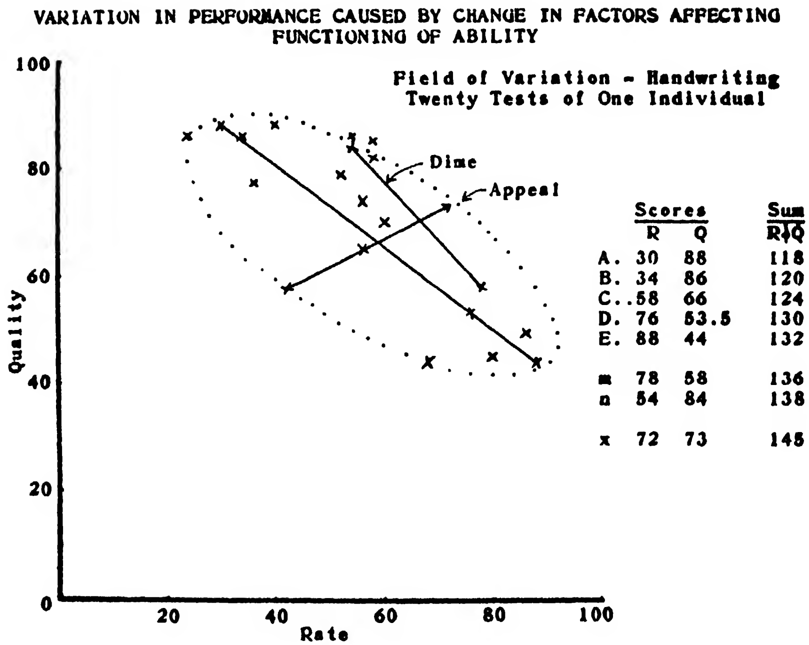


FIG. 17. The dotted ellipse represents a theoretical field of variation of score in handwriting of one individual tested under varying conditions; the crosses represent actual test results. Values A, B, C, D, E are scores which fall along the adjustment line; values mn represent the adjustment line when the child is putting forth more effort in response to a money incentive; X = score in response to an emotional appeal from the teacher. The minor axis of the ellipse represents the line of change in score caused by variations in effort put forth.

It should be noted that each of all these scores represents precisely the same ability in penmanship, if ability be defined in terms apart from the influence of special conditions. The child at will could and did in successive tests change from a score of 88 rate and 44 quality to a score of 30 rate and 88 quality and back again. Also, I wish to emphasize particularly that the instrumental and personal errors of each of these observations is approximately 2 per cent., so that the variation is in no way caused by inaccurate measurement. What we are dealing with here is varying performance accurately measured, not constant performance inaccurately measured. That is, the problem is one of analysis, not one of improvement of methods of measurement. The accuracy of the measurements exceeds greatly the effectiveness of our analytical technique.

Hypothetical analysis is possible to a degree, however. If the scores from Tests A, B and C are compared it will be found that they show a high degree of negative correlation. In general, there

is probably a law of adjustment for a mechanism which functions in performance and that law probably is that (for one individual) rate and quality are inversely proportional. Records are frequently secured, especially for adults, in which three or more scores maintain a constant relationship. If in a graph the same amount of space is used for both the rate and quality Ayres, one unit representing one letter per minute or one degree of merit on the Ayres scale, the most frequent angle made by the adjustment line with either axis is 45 degrees. In other words, the sum of rate and quantity is constant when rate is measured in letters written per minute and quality in terms of the Ayres handwriting scale. In the figure the major axis of the ellipse represents such an adjustment line, except that in this case it is not a 45° line and the scores of the various rates and qualities vary 7 per cent. either way from the average amount.

In one of the tests a strange examiner offered the children a dime if they would improve both their rates and qualities in a fast test and a slow test. The adjustment line of this particular pupil under this incentive is shown by the line marked "dime." Note that it is more clearly a 45° line and at a higher level than the major axis of the ellipse. The average sum of rate and quality for the major axis is 124; for the dime line is 137. The increase of 13 points is probably caused by the extra effort called out by the money incentive. In proof of this hypothesis the following facts are presented. After the strange examiner had departed, the regular room teacher told the children that she was deeply grieved to think that they would do so much better to win a dime or two than they would out of regard for her. She played upon their feelings with all the tricks of language at her command and then gave them another series of tests, appealing to them to prove they were not mercenary minded. The score 72–73 was the highest made and is 21 points higher than the mid-point, 124. On the other hand, the lowest score made on any test was one of a series given by the third of these strange examiners. The children became tired of the repeated tests and the low record was 24 points below the mid-point. The minor axis of the ellipse thus probably represents the range of variation in score caused by effort alone. Rate and quality are probably both directly proportional to effort and the elliptical field for any one student is the resultant of the play of the two factors, adjustment and effort.

On this theory, the fact that the apparent adjustment line of this individual is not a 45° line would be explained by saying that the directions for writing rapidly called out greater effort than the instructions to write well. However, there is at present no

COMPARISON OF COMPLEXITY OF PRODUCT MEASURED

Measure Used $\frac{\text{Semi-Annual Growth x 100}}{\text{Standard Deviation}}$

Results

Age	11	11.5	12
Height	73	72	63
Weight	68	65	57
Lung Capacity	59	55	46
Handwriting	53	48	41
Stanford	48	39	35
Intelligence	36	23	11

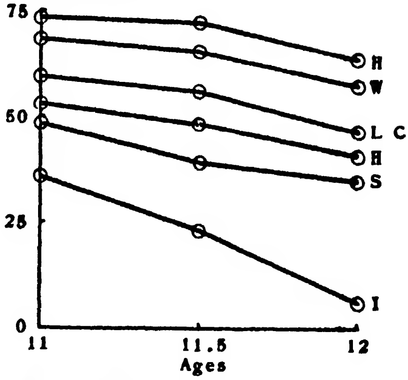


FIG. 18. The table is to be read as follows: If the ratio of semi-annual growth (×100) to the standard deviation of any trait is used as a measure of complexity, then for eleven-year-olds, height (73) is less complex than weight (.68). By this measure educational quantities are shown to be much more complex than physical quantities.

satisfactory method of measuring the effort component of a writing score and more exact determination of the relationship between these factors must await the invention of an adequate technique for measuring at least one of the pair singly.

My final illustration will deal with the complexity of educational products. I have adopted as a measure of complexity the percentage the semi-annual growth in mean score is of the standard deviations involved. Thus for age 11, the result for height is 73 per cent., for age 11.5, 72 per cent., for age 12, 63 per cent. Now height is a fairly stable characteristic, apparently determined largely by inherited forces of growth and affected relatively little by the incidents of life. Weight, on the other hand, varies with sickness, amount eaten, etc. Its index of complexity is lower. Lung capacity, the test of which involves voluntary effort, is lower still. Handwriting comes next. The composite score in the Stanford Achievement Test next, and intelligence scores based upon a composite of the army alpha and the national, lowest of all. At present the basic problem of education as a science is, therefore, the problem of analysis.

In view of this complexity and the fact of individual differences, the hope of rigid experimentation under the law of the single variable would seem to be slight. Actually, however, human nature is so variable that by matching pairs of individuals in a few significant traits two groups may be formed, composed of a very small

number of children, groups which nevertheless may be made as nearly equal as is desired.

In a group of 48 individuals the variations in handwriting ability from individual to individual was on the average 13 per cent. of the scores, the probable error of the distribution being 10.6 per cent. When pairs of individuals were matched in sex, age, intelligence, emotional stability and training, and groups of five formed, the differences in the average handwriting scores of the two groups, (scores of an ability in which they were not matched), fell to approximately 7 per cent. For groups of ten the difference in handwriting was a little more than 3 per cent., for groups of fifteen and twenty, less than 2 per cent., and for groups of twenty-four, but .2 of 1 per cent. On the other hand, the difference in the scores of the various groups in lung capacity, while not large (4 per cent.) were not affected by matching varying from slightly less than 2 per cent. to a little more than 5 per cent.

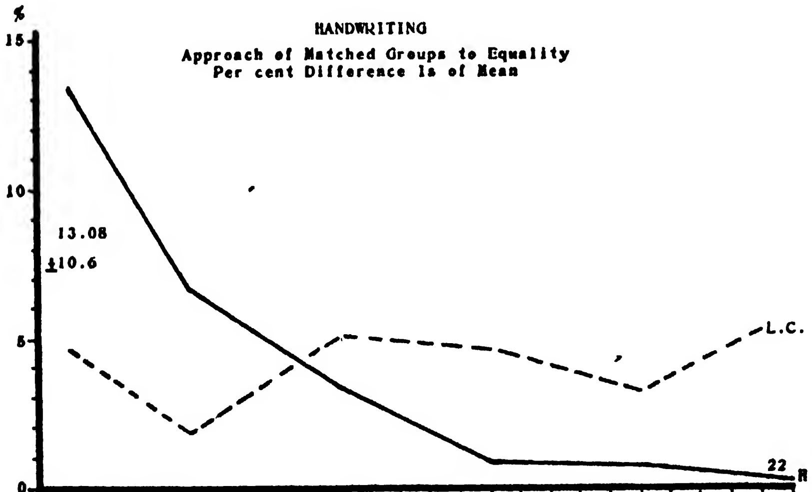


FIG. 19. The figure is to be read as follows: If any child is compared with any other child of the same age, sex, grade, intelligence and emotional rating, individual differences in handwriting ability are so great that the average difference for 48 cases was 13.08 per cent., half the cases falling within a range of 10.6 per cent. of this value. If instead of single scores the average score of matched groups of five such children are used, the difference in average of handwriting ability falls to 5.6 per cent., for groups of 10 to 3.3 per cent., etc.

By careful matching of pairs of individual children in essential characteristics it is possible to build up for experimental purposes two groups which shall be equal within any desired degree of accuracy.

H equals height. L. C. equals lung capacity.

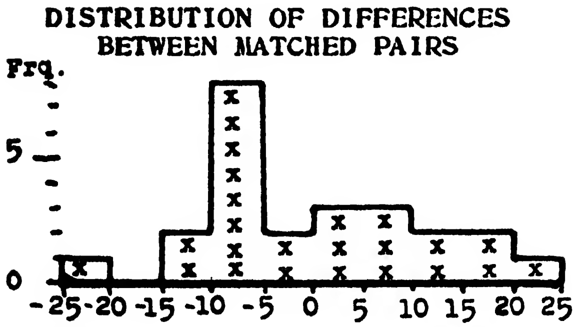


FIG. 20. Each X in the figure represents the difference in handwriting score of a pair of those individuals matched in sex, age, grade, intelligence and emotional rating which compose two groups of 24, whose average difference in handwriting was .2 per cent. The irregularities in the distribution show that the criteria used in matching were not completely adequate. In a control experiment changes in average values of groups to be acceptable would need to be confirmed by the tendency of the change in the differences of matched pairs.

The individual differences of the 24 matched pairs ranged from −21 to +21 but were fairly evenly distributed between the two groups. The excess of five differences at −5 and the deficiency at −15, however, mean that the criteria on which the individuals were matched are not quite adequate. Nevertheless, if one group were used as an experimental group and the other as a control group, any differences exceeding .5 of 1 per cent. resulting from the experimental factor could be detected. Thus, even with our present crude measuring instruments and our imperfect analytical technique, rigid experimental determination of the effects of such factors as method of teaching, selection of subject-matter, etc., is possible.

Education as a science, therefore, has measuring instruments and methods of experimentation more than adequate for present needs in the sense that many possible and valuable investigations have not yet been made. The greatest present-day lack is not for improved measuring instruments and new methods of procedure, but for adequately trained, scientifically minded men with time, opportunity and desire, to undertake the arduous labors of patient, painstaking research. This lack only time can supply. So I close as I began with the historical point of view and the prophecy that an important forward step in the formulation of fundamental concepts will be taken before 1945. This development will mark the beginning of the end of the transition period and will do much to establish education as a science even with those who can not now see the promise in the lusty infant because it is still wrapped in its swaddling clothes.

EVIDENCES FOR EVOLUTION

STATEMENTS PREPARED FOR THE DEFENSE COUNSEL, STATE OF TENNESSEE, VS. JOHN T. SCOPES

THE TRUTH OF EVOLUTION

By Dr. MAYNARD M. METCALF

THE JOHNS HOPKINS UNIVERSITY

INTELLIGENT teaching of biology or intelligent approach to any biological science is impossible if the established fact of evolution is omitted. Discussion of the methods by which evolution has been brought about is less essential, but the fact of evolution must be appreciated and the evolutionary point of view must be emphasized for any understanding of the growth of the universe, of the earth, of plants or animals; for any proper grasp of the facts of structure or function of living bodies as involved in medicine and in animal and plant husbandry; psychology, whether of normal or diseased minds, must constantly remember the processes of evolution; human societies, with their diverse customs, are unintelligible without the facts of their origins and changes, their evolution. God's growing revelation of Himself to the human soul can not be realized without recognition of the evolutionary method He has chosen. Teaching in any field that deals with living things is disgracefully, yes, criminally, inadequate if it omits emphasis upon evolution. An intelligent teacher could omit such emphasis only at the expense of his self-respect and of his moral integrity. Such teaching would be criminal malpractice just as truly as would be a physician's failure to follow established sound methods of treatment because of fear of persecution by ignorant neighbors. For a teacher to fail to bear testimony to essential scientific truth is as unworthy, as cowardly, as essentially sinful as for a man to fail to stand by his religion. Truth is one, whether scientific truth or religious truth, and it calls for loyalty from every worthy man. The fact of evolution—of man, of all living things, of the earth, of the sun, of the stars—is as fully established as the fact that the earth revolves around the sun. Change, growth, evolution, is a fundamental, a pivotal truth in all nature. Those familiar with the phenomena of nature testify with unanimity to this. The great mass of evidence of different sorts from different sources, when once seen, is overwhelmingly convincing to any normal, human mind. It can be only

the uninformed who fail to accept evolution as a fact established beyond doubt. On the other hand, there is great uncertainty as to the method by which evolution has been brought about. Many different factors have been in operation; among them probably the chief has been the mysterious intimate activities of the living substance itself about which as yet we know so little. As to the numerous "causes" of evolution and their relative importance there are about as many varieties of opinion as there are students of evolution. I am somewhat acquainted personally with nearly all the zoologists in America who have contributed extensively to the growth of knowledge in this field and I know many of the botanists and a goodly number of the geologists and I doubt if any two of these put exactly the same relative emphasis upon all the numerous interacting "causes" of evolution. But of all these hundreds of men not one fails to believe, as a matter of course, in view of the evidence, that evolution has occurred.

None of this, of course, has any bearing upon the question of God as the creator of the universe. It is only a matter of the method He has chosen in creation—whether immediate fiat or gradual growth accompanied by divergence. The evidence is overwhelming that the latter was and is His method. God is just as truly and just as intimately acting in the gradual growing of a plant from a seed or of a man from a fertilized egg as He would be in creating the full grown plant or man all at once in a thousandth part of a second of time.

There is no conflict, no least degree of conflict, between the Bible and the fact of evolution, but the literalist interpretation of the words of the Bible is not only puerile, it is insulting, both to God and to human intelligence.

But the fundamentalist would do much worse than insult God. He is in reality, although he doesn't realize this, trying to shut man's mind to God's ever-growing revelation of Himself to the human soul. He teaches, in effect, that God's revelation of Himself was completed long ago, that He long ago ceased to unfold His mind to men in new revelation. This is evil influence, criminal, damnable. Truth is sacred and to hinder men's approach to truth is as evil a thing, as unchristian a thing, as one can do. The thought that God is at odds with Himself, that his revelation of Himself to men of old is at variance with His works in nature is as blasphemous as it was for the Jewish leaders to say of Jesus that "He casts out devils through Beelzebub, the prince of the devils." Jesus made short work of this attack upon him.

No, the thing is not to attempt to guide God's self-revelation into channels of our own ignorant choosing, but is, rather, humbly

and in a wholly teachable spirit to seek His thought and Himself in nature, in history, in the vision of Himself He has given to men of old and is still giving to the humble-minded to-day. One of the greatest of God's revelations of Himself to men has come through His showing us His habit of producing results, by gradual growth, by evolution, rather than by immediate fiat.

Not only has evolution occurred; it is occurring to-day and occurring even under man's control. If one wishes a new vegetable or a new flower it is, within limits, true that he can order it from the plant breeder and in a few years he will produce it. Hundreds of new plants and animals have been and are being produced in this way. This is evolution of just the sort that has always occurred, only it is influenced by man's purpose. We can see evolution occurring in our experiment stations and our laboratories and we can control and modify the conditions of the experiments and can thus modify the resultant product to suit ourselves. Evolution is a present observable phenomenon as well as an established fact of past occurring. The organisms produced by this present-day controlled evolution in our experiments are as divergent from one another and from the original stock as are animals and plants in nature. The different kinds of domestic horses, produced by human experiment, differ far more than do the different kinds of horses found in nature. Domestic fowl under man's control have evolved into a large number of kinds far more widely divergent than are the wild kinds in the genus *Gallus* from which our domestic chickens came. The genus *Brassica,* plants belonging to the mustard family, include a number of different sorts of plants. One of these, *Brassica oleracea,* is the ancestor, the form from which man has evolved the cabbage, the cauliflower, kale, Brussels sprouts, Kohl rabi and the Swedish turnip, which differ among themselves far more than do the wild members of the genus *Brassica.* The same sort of thing is seen in hundreds of domestic animals and plants, dogs, cattle, sheep, pigeons, cucumbers, radishes, lettuce, dahlias, roses, wheats, corns, strawberries, peaches, apples, pears, etc. This is all true evolution and is going forward to-day with ever-increasing strides. To describe adequately the tremendous mass of phenomena which establish the fact of past and continuing evolution would require not a book or a series of books, but a library. In the main these evidences may be arranged in four chief groups: (1) The phenomena of comparative anatomy; (2) the phenomena of comparative embryology; (3) the phenomena of paleontology and geology, and (4) the phenomena of geographical distribution. Much in the fields of physiology, psychology and human cultures has very important bearing upon evolution.

(1) We can arrange plants and animals in a double parallel series showing increasing complexity of organization.

(2) In the development of an individual from egg to adult this individual passes through a series of stages of increasing complexity and this individual series in one of the higher organisms strangely parallels and agrees with the racial series first mentioned.

(3) In the fossiliferous rocks we find actual bodily remains of organisms of the past and these form a series showing increasing complexity within each taxonomic group, the animals and plants in the older rocks being more simple, while the successively younger rocks show more and more complex organisms in each group under observation.

(4) The distribution of animals and plants over the earth is such as to suggest strongly the origin of each group of animals or plants at some one place, and their gradual spread from that center, divergent évolution occurring while they are spreading. No other suggestion even plausible, let alone convincing, has been made to explain these phenomena. Evolution is the only key we can find.

In each of the four groups of phenomena mentioned there are many very striking things. One set of these things, in the first, morphological group, is that of the vestigial organs in animals and plants. There are in man, for example, very many structures of no conceivable present use, but showing resemblance to organs in other animals which are useful. The appendix vermiformis is one such structure, a mere vestige of an organ of great importance in some lower mammals. The human tail—bony coccyx with its rudimentary muscles—is another. The wisdom teeth of man are approaching a vestigial condition.

It is interesting to observe that an organ in one kind of animal may have a different use from the similar organ in a related animal. There are very few, if any, structures in man, for example, which do not show clear indications of relationship to, descent from, an organ of different use in some related animal. The lungs of man correspond to the swim bladder of fishes; hair has apparently been derived from tactile sense organs in the skin of aquatic vertebrates; certain bones connected with the human larynx were derived from the supporting arches in the bars between the gill slits of our aquatic ancestors; our teeth were once scales in the skin; and so on and so on. Probably there is no structure in the human body which was not at some time used for a different purpose. As the use of an organ changes, in evolution, its structure correspondingly changes and we see most complete series of intergrades between the earlier and the later conditions.

In all this discussion I have not used the word "species." There are no such things as species in nature. In nature we find different kinds of animals and plants. The words "species," "genus," "family," etc., are terms used to describe the fact that animals and plants differ among themselves and differ to different degrees. Those that are closely similar, that is closely related, we class in one species; those less closely related, but still not too different, we place in different species, putting the related species together in one genus; and so on. Species, genera and so forth, are man-made pigeon-holes in which to classify the real animals and plants seen in nature. I have recently made about 150 species of protozoa, but I have never made an animal. The word species is indefinable, and is used by biologists merely as a convenience, and it has wholly different meanings when applied to different groups of animals and plants. There are many genera of animals and plants in which most or all the species completely intergrade so that specific distinctions are purely artificial. This is true to large degree among the protozoan forms I have been studying recently. I have made species among them on the basis of distinctions far too minute to be considered for a moment as of "specific" value among, say, insects or mammals.

THE FACT, THE COURSE AND THE CAUSES OF ORGANIC EVOLUTION

By Dr. WINTERTON C. CURTIS

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At this point we may examine a common misunderstanding with reference to evolution and the work of Charles Darwin. Suppose we begin with an analogy, illustrating what may be termed the *Fact*, the *Course* and the *Causes* in a progressive series of events. A ship leaves a European port and sails across the Atlantic to New York harbor. We may distinguish between: (1) the fact that the ship actually crossed the ocean, instead of being "created" in the harbor of New York; (2) the course the ship may have pursued, whether direct or indirect, and the like; and (3) the causes that made the ship go, whether an internal propelling force like steam or electricity, an external force like wind or current or even direction by wireless. Compared with the doctrine of evolution, we have: (1) The fact of evolution, as representing the historical series of events; (2) the course followed in evolution, for instance, whether the land vertebrates arose from the fish-like ancestors, birds from

reptiles or the like; and (3) the causes of evolution or what made and makes it happen. These three aspects, like those in the voyage of a ship, are separate though related items. They must be constantly distinguished, if there is to be any clear thinking on this matter by one who is not a scientist.

It is now possible to explain the misunderstanding above cited. The historical fact of evolution seems attested by overwhelming evidence. Science has nothing to conceal, it stands "strong in the strength of demonstrable facts," and invites you to view the evidence. The course pursued by evolution is known broadly in many instances, but in the nature of the case the evidence is limited and many of the steps will always remain uncertain, without, however, a calling in question of the historic fact. The causes of evolution present the most difficult problem of all and the one regarding which we know the least. The recent strictures of Professor Bateson, which have been exploited by anti-evolutionists, were directed wholly at current explanations of evolutionary causation and the course of evolution. He affirmed his belief in the historic fact when he said "our faith in evolution is unshaken"—meaning by "faith," of course, *a reasonable belief resting upon evidence.*

That such an interpretation of Professor Bateson's views is the correct one appears from the following communication:

11 December 1922
The Manor House,
Merton
London, S. W. 20.

Dear Professor Curtis:

The papers you have sent me relating to the case of Mr. ———— give a curious picture of life under democracy. We may count ourselves happy if we are not all hanged like the Clerk of Chatham, with our pens and ink horns about our necks!

I have looked through my Toronto address again. I see nothing in it which can be construed as expressing doubt as to the main fact of Evolution. In the last paragraph (copy enclosed) you will find a statement in the most explicit words I could find, giving the opinion which appears to me forced upon us by the facts—an opinion shared, I suppose, by every man of science in the world.

At Toronto I was addressing an audience, mainly professional. I took occasion to call the attention of my colleagues to the loose thinking and unproven assumptions which pass current as to the actual processes of evolution. We do know that the plants and animals, including most certainly man, have been evolved from other and very different forms of life. As to the nature of this process of evolution, we have many conjectures, but little positive knowledge. That is as much of the matter as can be made clear without special study, as you and I very well know.

The campaign against the teaching of evolution is a terrible example of the way in which truth can be perverted by the ignorant. You may use as much of this letter as you like, and I hope it may be of service.

Very truly,
W. BATESON.

The paragraph to which Professor Bateson refers above is the concluding one of his address and runs as follows:

> I have put before you very frankly the considerations which have made us agnostic as to the actual mode and processes of evolution. When such confessions are made the enemies of science see their chance. If we can not declare here and now how species arose, they will obligingly offer us the solutions with which obscurantism is satisfied. Let us then proclaim in precise and unmistakable language that our faith in evolution is unshaken. Every available line of argument converges on this inevitable conclusion. The obscurantist has nothing to suggest which is worth a moment's attention. The difficulties which weigh upon the professional biologist need not trouble the layman. Our doubts are not as to the reality or truth of evolution, but as to the origin of *species*, a technical, almost domestic, problem. Any day that mystery may be solved. The discoveries of the last twenty-five years enable us for the first time to discuss these questions intelligently and on a basis of fact. That synthesis will follow on an analysis, we do not and can not doubt.

With this distinction between fact, course and causes clearly in mind, the significance of Darwin's work in the history of biological thought can be understood. Darwin's accomplishment was twofold. In the first place, he established organic evolution as the only reasonable explanation of the past history of living things. Secondly, he offered, in natural selection, what then appeared an adequate explanation for the origin of species and hence for the *causes* of evolution. Darwin's evolutionary argument in his "Origin of Species" was that one species could give rise to another "by means," as he believed, "of natural selection or the preservation of favored races in the struggle for life." If one species could be shown to give rise to another, the same process could be continued. No limit could be set. The types thus produced could depart indefinitely from the parent form. Once the mutability of species be admitted, the only reasonable conclusion is that evolution has taken place. His argument was supported by an immense collection of facts along observational and experimental lines. The total result was overwhelming, coming as it did more than one hundred years after the original promulgation of the theory of transmutation and its repeated rejection by the main body of naturalists. Evolution was accepted so quickly by scientists that the world was startled. This sudden conversion gave rise to the impression, even among scientific workers, that no serious contribution to evolutionary theory had been made before the work of Darwin. Such an impression does not represent the facts and it does grave injustice to the pioneer thinkers of the eighteenth century to whom we have alluded.

Darwin's second accomplishment, natural selection, was accepted by science as a causo-mechanical explanation of evolutionary

change. The cogent statement and the simplicity of the principle of selection were of great importance for its acceptance as the cause of evolution, along with the broader theory of evolution as the historic fact. Extended exposition of the selection process will not be attempted. It may be found in numerous elementary reference books and in the early chapters of the "Origin of Species." The tabulation known as *Wallace's Chart,* which is an admirable outline of the argument, may be cited in this connection:

WALLACE'S CHART OF NATURAL SELECTION

	Proved Facts	*Consequences*
A	Rapid Increase of Numbers	Struggle for Existence
B	Total numbers Stationary	
C	Struggle for Existence	Survival of the Fittest (Natural Selection)
D	Variation and Heredity	
E	Survival of the Fittest	Structural Modifications
F	Change of Environment	

The importance of Darwin's work in the history of scientific thought is that it *convinced science of the truth of organic evolution and proposed a then plausible theory of evolutionary causation.* Since Darwin's time, evolution as the historic fact has received confirmation on every hand. It is now regarded by competent scientists as the only rational explanation of an overwhelming mass of facts. Its strength lies in the extent to which it gives meaning to so many phenomena that would be meaningless without such an hypothesis.

But the case of natural selection is far different. Of recent years, this theory of the causes of evolution has suffered a decline. No other hypothesis, however, has completely displaced it. It remains the most satisfactory explanation of the origin of adaptations, although its all-sufficiency is no longer accepted. The initial step in evolution is the *appearance* of individual variations which are perpetuated by heredity, rather than the *selection* of variations after they have appeared. The interest of investigators has shifted to problems of variation and heredity, as exemplified by the rise of the science of genetics.

As a result of this situation, there has been much discussion among scientists regarding the adequacy of what is often referred to as the *Darwinian theory,* meaning *natural selection.* In condemning *selection* as an inadequate explanation of the problem, biologists have often seemed to condemn *evolution itself.* It is not strange that the layman, for whom Darwinism and evolution are synonymous terms, believes that evolution has been rejected when

he hears that belief in Darwinism is on the wane. He does not understand that what is thus meant by Darwinism is not the historic fact of evolution, but the proposed cause of evolution—natural selection. This point may not seem vital, but those interested in biological science frequently find the situation used to support claims that the entire concept of organic evolution has fallen into disrepute. There are many, even to-day, who rejoice at anything that appears to weaken this major generalization of biology.

Such then is the more strictly scientific status of the doctrine of evolution as a whole. The origin, by evolution, of the heavenly bodies and of our earth is evidenced by facts of astronomy and geology as set forth in any elementary treatise on these sciences. Inorganic evolution or the modification of non-living matter is thus supported by science and does not find serious opposition in the public mind. Organic evolution or the origin of animal and plant life receives a similar support from the facts of biology. If the origin of man were not involved, there would be presumably little serious opposition from non-scientific sources at the present day.

Human Evolution

But with the evolution of all other living things, both animal and plant, overwhelmingly attested by the facts, it is not only impossible but puerile to separate man from the general course of events. Moreover, the evidence for man's origin is becoming clearer year by year. Comparative anatomy, embryology, classification, physiology, geographical distribution, fossils and the existing races of mankind tell the same story for man as for the rest of the animal world.

Huxley's essay, entitled "Man's Place in Nature," presents in a masterful manner the anatomical evidence for our kinship with the four species of tailless apes—the gibbon, gorilla, orang and chimpanzee—and his most significant conclusions are even more strongly established at the present day. If creation occurred "at 9:00 A. M., on October 23, of the year 4004 B. C." as part of the divine plan, it is amazing that such success should have dogged the steps of the students of human skeletal and cultural remains during the last half century. The skeletons in part or in whole are known for a number of sub-human races and a vast array of implements and other remains, all showing a progressive advancement. By another fifty years, it seems safe to expect that much more of the story will be unveiled. It is further amazing that investigations in Egypt show the existence of a flourishing civilization in the Nile Valley as early as 5000 B. C., and back of this a gradual development from the barbarism of the stone age.

On man's intellectual side, psychology is making increasingly evident the essentially animal foundation of human intelligence. Man's claim to importance in the universe revealed by science lies not in the pretense that this planet was created for his convenience, but in the claim that he transcends the material universe in so far as he comprehends it. And the method of such comprehension that dominates modern thought is the method of science, not that of theology.

The question of human beginnings is one that is open to investigation like any other historic or prehistoric event. In this connection a quotation from a famous essay by Herbert Spencer, published in 1852, is appropriate:

> Those who cavalierly reject the Theory of Evolution, as not adequately supported by facts, seem quite to forget that their own theory is supported by no facts at all. Like the majority of men who are born to a given belief, they demand the most rigorous proof of any adverse belief, but assume that their own needs none. Here we find, scattered over the globe, vegetable and animal organisms numbering, of the one kind (according to Humboldt) some 320,000 species, and of the other some 2,000,000 species (see Carpenter); and if to these we add the numbers of animal and vegetable species that have become extinct, we may safely estimate the number of species that have existed, and are existing, on the earth, at not less than ten millions. Well, which is the most rational theory about these ten million of species? Is it most likely that there have been ten millions of special creations? Or is it most likely that by continual modifications, due to change of circumstances, ten millions of varieties have been produced, as varieties are being produced still?

And, one might add, if the evidence indicates that all other species have arisen by evolution, it is probable that man, whose bodily structure and functions are so nearly identical with those of the mammalia and particularly the primates—that man arose in a different fashion. We have, moreover, as above indicated, the positive evidence to support this general presumption.

Having outlined the evidence for human evolution and stated the presumption in its favor, let us turn to the evidence for special creation, as found in Genesis. Science and common sense alike inquire regarding the nature and sources of this account, if it be regarded as a true statement of the facts. Science faces the matter squarely, desiring only the right to investigate and draw unprejudiced conclusions. The results of such investigations are not in doubt. It appears that the races about the eastern Mediterranean, like other primitive peoples, had their traditions of the origin of the world. The story in Genesis apparently descended to the early Hebrews and to their neighbors in Mesopotamia from a source far antedating the appearance of the Jews as a people and their sacred writings. Archeology and ethnology most reasonably indicate that

in its origin this Hebrew-Babylonian tradition may be compared with the stories of many other primitive peoples. We take the story in Genesis seriously as an account of prehistorical facts, because it is *our* story of creation passed down by tradition from *our* fathers. It is and will remain sacred and interesting, because it has been woven into the thought of western culture for almost two thousand years and because of its intrinsic literary and moral qualities.

But the past history of events, whether of human or animal origins, is subject-matter for scientific inquiry, and the answer of science is evolution. The very great antiquity of man, the existence at an earlier period of beings, man-like, but intermediate between man and other primates, together with the facts of man's anatomy, his embryology, his physiological reactions, even his mentality, all point to his bodily kinship wth the rest of living nature. It is not that men came from monkeys, but that men, monkeys and apes all came from a common mammalian ancestry millions of years in the past.

It is more reasonable to believe that the Bible is a human document, representing the history of an advance from the concept of a barbarous and vengeful Jehovah of the earlier Old Testament, through the God of righteousness and justice of the later prophets, and culminating in the concept of a Father as preached by Jesus of Nazareth.

In the foregoing statement we have considered the intellectual aspects of the doctrine of organic evolution. There remain its social aspects. Evolution is one of the basic concepts in modern thought. Suppression of a doctrine established by such overwhelming evidence is a serious matter. From the standpoint of the teacher the situation has more than academic interest.

Evolution has been generally accepted by the intellectually competent who have taken the trouble to inform themselves with an open mind. The following letter was written in response to a request to state his position, it having been alleged thet he was not a believer in organic evolution:

Washington, D. C.
29th August 1922

My dear Professor Curtis:

May it not suffice for me to say, in reply to your letter of August twenty-fifth, that of course like every other man of intelligence and education I do believe in Organic Evolution. It surprises me that at this late date such questions should be raised.

Sincerely yours,
WOODROW WILSON

Professor W. C. Curtis,
Columbia, Missouri.

In view of all the facts, may we not say that the present storm against organic evolution is but an expression of malign influences of prejudice and ignorance, hostile to what we may envision as the high destiny of our western world.

EVIDENCES FROM COMPARATIVE ANATOMY

By Dr. H. H. NEWMAN

PROFESSOR OF ZOOLOGY, UNIVERSITY OF CHICAGO

THE foundation stones of comparative anatomy are the principles of homology and of analogy. The former implies heredity and the latter variation.

THE PRINCIPLE OF HOMOLOGY

Any one who has at all seriously studied comparative anatomy must have been impressed with the fact that the animal kingdom exhibits several distinct main types of architecture, each of which characterizes one of the grand divisions of the kingdom. Within each of these great assemblages of animals characterized by a common plan of organization there are almost innumerable structural diversities within the scope of the fundamental plan. These major or minor departures from the ideally generalized condition remind one of variations upon a theme in music; no matter how elaborate the variation may be, the skilled musician recognizes the common theme running through it all. This fundamental unity amidst minor diversity of form or of function is looked upon as a common inheritance from a more or less remote ancestor. In animals belonging to the same group and therefore having the same general plan of organization we find many organs having the same embryonic origin and the same general relations to other structures, but with vastly different superficial appearance and playing quite diverse functional rôles. Such structures are said to be homologous.

A common example of homologous structures is presented by the fore limbs of various types of backboned animals (vertebrates): such, for example, as that of man, that of the whale, that of the bird and that of the horse. The arm of man is by far the most generalized of these; it is not far from the ideal prototypic land vertebrate fore limb, in that it is not specialized for any particular function but is a versatile tool of the brain. The flipper of the whale is a short, broad, paddle-like structure, apparently without digits, wrist, fore arm or upper arm; but on close examination it is seen to possess all these structures in a condition homologous almost bone for

bone and muscle for muscle with those of the human arm. The wing of the bird, a highly specialized organ of flight, appears superficially to have nothing in common with the arm of man; but a study of its anatomy shows the same bony architecture and muscle complex, modified rather profoundly for a different function and with the thumb and two of the fingers greatly reduced or entirely unrepresented in the adult stage. The fore leg of the horse is a specialized cursorial appendage, and in accord with this function has but one functional toe with a heavy toe-nail or hoof. Two other toes are represented by the so-called splint bones, mere vestiges of once useful structures. In other respects the horse's leg is quite homologous with that of other land vertebrates. The evolutionary explanation of the fact that these several types of limbs (each playing an entirely different rôle in nature and each so unlike the other in form and proportions) have the same fundamental architecture is that they have all inherited these characters from some distant common ancestor. In each case the inheritance has undergone modification in harmony with the life needs of the organism. This of course implies descent with modification, which is no more or less than evolution.

An equally significant situation comes to light in connection with the hind limbs of vertebrates. The leg of man, a specialized walking appendage, is much less versatile than is the arm, yet it is closely homologous with the latter. The hind limb of the whale is in some species entirely wanting in the adult or else is in vestigial condition. The leg of the bird is decidedly reptilian in structure and is believed to have retained in large measure the characteristics of that of the supposed reptilian ancestors. The hind limb of the horse, though somewhat stronger and heavier than the fore limb, resembles the latter closely both in form and function. Snakes are typically limbless vertebrates, but the python has small but clearly defined hind limbs, somewhat reduced in number of bones and almost entirely hidden beneath the scaly integument.

No other attempt to explain homologies such as those briefly outlined above has been made except that of special creation, and this implies a slavish adherence to a preconceived ideal plan together with capricious departures from the plan in various instances. A systematic attempt to apply the special creation concept to all cases of homologies involves one in the utmost confusion of ideas and leads almost inevitably to irreverence, which is abhorrent to evolutionist as well as to special creationist.

Vestigial Structures

These may be defined as functionless rudiments of structures whose homologues are found in a functional state in other members

of a group with a common architectural plan. Thus the hind limbs of the whale and of the python, the thumb of the bird, the splint bones of the horse, are vestigial homologues of structures well developed in more generalized groups of vertebrates.

The case of the hind limb vestiges in the various species of whales may be emphasized as a crucial one. Several different degrees of rudimentation are found in different types of whales, ranging from a state in which the pelvic bones and those of most of the leg are clearly recognizable as such down to one in which these bones are entirely absent in the adult condition. In the cases where the bones are obvious, the situation is just this: deeply buried beneath the thick cushion of blubber in the pelvic region there lies a little handful of bones, ridiculously minute in comparison with the giant proportions of the other parts of the skeleton. These bones are immovable because their muscular connections are atrophied; they do no service in supporting the frame of the animal; in short, they can not possibly function as bones at all. The somewhat puerile argument of the anti-evolutionist that these vestigial limb bones play some useful though unknown rôle, else they would never have been created, can not seriously be entertained in this case, for what can they make of the fact that some whales entirely lack these structures? More difficult even than this for the special creationist to explain is the fact that, even in those whales that lack vestigial limb bones in the adult condition, posterior limb buds appear in the early embryonic period and then slowly atrophy. The case just described is in no way exceptional or peculiar. It is, on the contrary, quite typical of a very general phenomenon.

Vestigial Structures in Man

There are, according to Wiedersheim, no less than 180 vestigial structures in the human body, sufficient to make of a man a veritable walking museum of antiquities. Among these are: the vermiform appendix; the abbreviated tail with its set of caudal muscles; a complicated set of muscles homologous with those employed by other animals for moving their ears, but practically functionless in all but a very few men; a complete equipment of scalp muscles used by other animals for erecting the hair but of very doubtful utility in man even in the rare instances when they function voluntarily; gill slits in the embryo, the homologues of which are used in aquatic respiration; miniature third eyelids (nictitating membranes), functional in all reptiles and birds, greatly reduced or vestigial in all mammals; the lanugo, a complete coating of embryonic down or hair, which disappears long before birth and can hardly serve any useful function while it lasts. These and numerous other

structures of the same sort can be reasonably interpreted as evidence that man has descended from ancestors in which these organs were functional. Man has never completely lost these characters; he continues to inherit them, though he no longer has any use for them. Heredity is stubborn and tenacious, clinging persistently to vestiges of all that the race has once possessed, though chiefly concerned in bringing to perfection the more recent adaptive features of the race.

Homology versus Analogy

It is quite common to find different animals with certain structures that look alike and function alike but are not homologous. The eye of the octopus, a cephalopod mollusc, has a chorion, a lens, a retina, an optic nerve and a general aspect decidedly like that of a fish. As an optical instrument it must obviously function in the same manner as does the eye of an aquatic vertebrate; but not one part of the eye of a cephalopod is homologous with that of a vertebrate. Because these two types of eye look alike and function alike, but arise from quite different embryonic primordia adapted to meet a common function, they are known as analogous structures. They are to be sharply contrasted with homologous structures, which may be widely different in form and function so long as they arise from equivalent embryonic primordia. Both homologies and analogies imply changes in relation to the environment and therefore plainly favor the idea of descent with modification.

Connecting Links

If one group of animals has been derived by descent from another there should be some forms more or less intermediate between the two and with some characteristics of both groups. Many such connecting links actually exist at the present time. Almost every order of animals possesses some primitive members that have doubtless evolved at a slower rate than their relatives and have on that account retained a larger measure of ancestral traits than have the more typical representatives of the group. Thus there is a group of primitive annelid worms, represented by Dinophilus, Protordrillus and Pollygordius that serve partially to bridge the gap between the two grand divisions, annelids and flatworms. The case of the several species of Dinophilus is especially noteworthy, for these little animals are so evenly balanced between the characteristics of one phylum and those of the other that some authors place them among the flatworms, others among the annelids and still others are inclined to place them in an anomalous group by themselves. There is an interesting genus of primitive centipedes, called Peri-

patus, which possesses about as many annelid features as arthropod features. Among vertebrates we have the familiar example of the lung fishes with both the gills of fishes and lungs homologous with those of land vertebrates. And finally, we may mention those curious egg-laying mammals, monotremes, of Australia and New Zealand, which though obviously mammalian in most respects, possess, in addition to laying eggs after the fashion of reptiles, many other decidedly reptilian traits. The reader interested in following up in more detail this interesting branch of comparative anatomy will find the subject skilfully handled by Geoffroy Smith in a volume entitled "Primitive Animals."

Comparative anatomy is a mature and well-organized science and involves a vast amount of technical data. No one but a trained comparative anatomist can reasonably be expected to appreciate the dependence of this subject upon the principle of evolution. Without evolution as a guiding principle comparative anatomy would be a hopeless mass of meaningless and disconnected facts; with the aid of the principle of homology, an evolutionary assumption, it has grown to be one of the most scientific branches of biology. This may be taken as an illustration of the nature of the proof of organic evolution; that when it is used as a working hypothesis or guiding principle, it really works in that it is not only consistent with all the facts, but lends significance and interest to facts that would otherwise be drab and disconnected.

Evidences from Classification

The object of classification is to arrange all species of animals and plants in groups of various degrees of inclusiveness which shall express as closely as possible the actual degrees of relationship existing between them. In pursuance of this object we begin by grouping together as one species all animals that are essentially alike in their anatomical details. As an example of the methods of classification we may take the following familiar instance: the European wolf is a particular kind of animal constituting a species called lupus (the Latin word for wolf) all members of which are more like one another than they are like wolves of other sorts, for the reason that they have a common inheritance. There are not a few other species of wolves, each given a Latin name, and all these wolf species, including dogs (believed to be domesticated and therefore highly modified wolves) are placed in one genus, Canis. Several other genera of more or less wolflike animals, such as jackals and foxes, are grouped with the genus Canis and constitute the family Canidae, the assumption being that they are all the diversified descendants of some common wolflike ancestor. Other families,

such as the Cat Family (Felidae), the Bear Family (Ursidae) and several other families of terrestrial beasts of prey, constitute the suborder Fissipedia. These in turn are grouped with the marine beasts of prey, such as seals, sea-lions, walruses (suborder Pinnipedia) to form the mammalian order, Carnivora. Several other orders of animals with many characteristics in common are combined to form the class Mammalia, which is one of several classes belonging to the subphylum Vertebrata, a branch of the phylum Chordata. A phylum is one of the grand subdivisions of the animal kingdom and is made up of species with the same fundamental plan of organization, the common features of which are believed to be derived from a common ancestral type.

The underlying assumption of classification is the same that underlies comparative anatomy; that degrees of resemblance run parallel with degrees of blood relationship, that the most nearly identical individuals are most closely related and that those that bear the least fundamental resemblance to each other are either not genetically related at all or else had a common ancestor far back in the misty past when animal life was in process of origin. We have already shown that this assumption holds good in all cases where it has been possible to put it to the test. No further justification need be offered in this place for making use of the only adequate instrument of classification: the principle of homology.

What is a Species?

The species is the unit of classification, but there is serious doubt as to whether species have any reality outside of the minds of taxonomists. Certainly it is extremely difficult, if at all possible, exactly to draw sharp boundary lines between closely similar species. When we examine a large number of individuals belonging to a given species we find that there are no two exactly alike in all respects. As a rule there is a wide range of diversity within the limits of the group we call a species, and the extreme variants are often so unlike the type form that were it not for the intergrading steps between them they would often be adjudged distinct species. Moreover, the species of a prosperous genus are so variable that it becomes an almost impossible task to determine where one species ends and another begins, so closely do they intergrade one into another. A species, then, is not a fixed and definite assemblage such as one would expect it to be if specially created as an immutable thing. On the contrary, intensive study of any widely distributed species gives the impression of an intricate network of interrelated individuals changing in a great variety of ways.

The completed classification of any large group, such as the vertebrates, presents itself as an elaborately branching system whose resemblance to a tree is unmistakable. The phylum branches into subphyla, some of the latter into several classes, classes into orders, orders into families, families into genera, genera into species, species into varieties. We may compare the phylum to one of the main branches coming off from the trunk, while the varieties may be thought of as the terminal twigs. This tree-like arrangement is exactly what one would expect to find in a group descended from a common ancestry and modified along many different lines. It is in reality a genealogical tree. If this striking arrangement is a part of the plan of special creation it is indeed strangely unfortunate that it speaks so plainly of descent with modification.

Man's Place in the System of Classification

There is no greater difficulty in connection with the classification of man than in that of any other living species. Indeed there are scores, even hundreds, of species whose exact affinities with other groups are far less obvious than those of the human species. Anatomically, the genus Homo bears a striking resemblance to the anthropoid apes. Bone for bone, muscle for muscle, nerve for nerve, and in many special details, man and the anthropoid apes are extremely similar. Homologies are so obvious that even the novice in comparative anatomy notes them at a glance. Man is many degrees closer anatomically to the great apes than the latter are to the true monkeys, yet the special creationist insists upon placing man in biological isolation as a creature without affinities to the animal world. If a man is a creature apart from all animals it is extremely difficult to understand the significance of the fact that he is constructed along lines so closely similar to those of certain animals; that his processes of reproduction are exactly those of other animals; that in his development he shows the closest parallelism step for step to the apes; that his modes of nutrition, respiration, excretion, involve the same chemical processes; and that even his fundamental psychological processes are of the same kind, though differing in degree of specialization, as are those of lower animals.

Comparative anatomists recognize man as a vertebrate, for he has all the characteristic features of that group. He is obviously a mammal, for he complies with qualifications of that class in having hair; in giving birth to living young after a period of uterine development; in suckling the young by means of mammary glands; in having two sets of teeth, one succeeding the other; in having the teeth differentiated into incisors, canines and molars; and in many other particulars of skeleton, muscular system, circulatory system,

alimentary system, brain and other parts of the central nervous system. Among mammals, man belongs to the well-defined order of Primates, an order anatomically about half way between the most generalized and the most specialized of the mammalian orders. Apart from his extraordinary nervous specialization, man is a relatively generalized mammal as compared with such highly specialized types as, for example, the whales. The older taxonomists place man and the other primates at the top of the genealogical tree, assigning to him the central tip of the central branch as though the goal of all organic evolution were man. Accordingly, those mammals such as the whales, which are least like man, were considered the lowest members of the class. There has been within recent years a pronounced reversal of this anthropocentric point of view, which has resulted in a complete revision of the arrangement of mammalian orders, with the Insectivora the lowest, the Cetacea (whales) the highest, and the Primates about intermediate in systematic position.

The order Primates consists of two suborders—Lemuroidea and Anthropoidea. The lemurs or half apes are small arboreal animals with somewhat squirrel-like habits but with flat nails and certain other primate characters. They serve to link up the Primates with the most primitive of the mammalian orders, the Insectivora, which are now believed, on anatomical and paleontological grounds, to be ancestral not only to the primates but to most of the other modern mammalian orders. The anthropoid or man-like Primates are divided into four distinct families: the Hapalidae or marmosets; the Cercopithecidae or New World monkeys; the Simiidae or anthropoid apes; and the Hominidae or men. The family Hominidae includes four genera: The genus Pithecanthropus, represented by the fragmentary remains of an extinct Javan ape-man, the genus Paleanthropus, the genus Eanthropus and the genus Homo, including in addition to the existing species Homo sapiens, several different extinct human species known as the Dawn Man, the Neandertal Man, the Rhodesian Man and others.

The species Homo sapiens consists of at least four sub-species or major varieties, each consisting of numerous minor races and admixtures of these. This high degree of diversity within the species is evidence of rapid evolution. If a little over four thousand years ago, as the special creationists claim, one man was created and has become the ancestor of all men living to-day, evolution must have gone on at an extremely rapid rate in order to have produced so many widely different races, for there could scarcely have been more than one hundred and twenty generations in that time. If species are believed to be immutable it is difficult to understand why man should be such a diversified group as he is.

ORGANIC EVOLUTION FROM THE POINT OF VIEW OF THE SOIL INVESTIGATOR

By Dr. JACOB G. LIPMAN

DEAN OF THE COLLEGE OF AGRICULTURE AND DIRECTOR OF THE NEW JERSEY AGRICULTURAL EXPERIMENT STATION, STATE UNIVERSITY OF NEW JERSEY

THE student of soils is obliged to consider the materials from which they are made. These materials are represented by rocks and minerals, and by the remains of plants, animals, insects, bacteria and other microorganisms. The change of rocks into soils is a slow and gradual process. In the older geological ages the mantle of soil covering the rocks was not as thick as it is to-day. Going back far enough, we come to the time when the depth of soil was not great enough to support plants of any but very primitive forms. Like plants and animals, our soils had to pass through a long period of change to support the varied forms of life on the earth. A direct relation may be traced between soils, plants and animals in the evolution of organic life.

Among the early forms of life there were bacteria capable of developing in a purely mineral medium. Such forms are still found in the sea, in mineral springs and in soils. Some of them can obtain the energy for their life processes by oxidizing hydrogen gas, methane (marsh gas), carbon monoxide, sulphur, sulphuretted hydrogen, iron and even carbon. In the primitive seas, and on the rock surfaces, these simple forms of life prepared the way for the more highly organized beings. Some bacteria are able to manufacture nitrogen compounds out of the simple nitrogen gas of the air. They thus supply material out of which the protoplasm of plant and animal cells is made. Other bacteria convert the nitrogen of plant and animal substances into ammonia and nitrates. Mineral acids, like nitrous, nitric, sulphuric and phosphoric, are partly, if not entirely, the products of bacterial activity. Carbon dioxide is generated in enormous quantities through the activities of microorganisms. In the course of ages the by-products of microbial activity served to dissolve enormous quantities of rock material, and this dissolved material started on its way to the sea. Silicates, phosphates, nitrates, sulphates and carbonates went to supply the building stones for the bodies of marine organisms. Some of the salts dissolved from the rocks ultimately became the source of salt deposits, such as rock salt, gypsum, potash, salts, limestone, etc. Bacteria are thus recognized as the primary or secondary cause of extensive mineral deposits, in other words, as geological agents of importance. By way of example, mention may be made of the potash deposits

of certain European countries, estimated to be twenty million years old. The green sand formation of New Jersey and states further south originated in the sea about ten million years ago. The phosphate deposits of Central Tennessee are derived from limestone rock fifty million years old at the very lowest estimate. The extensive deposits of coal represent the remains of ancient vegetation. We are now burning coal derived from plants that grew at least twenty million years ago. The coal deposits contain nitrogen which to-day is the source of fertilizer. In making coke, illuminating gas and other products from coal, a large part of the nitrogen is saved and converted into ammonia for refrigeration and fertilizer purposes. We know of extensive deposits of sulphur which originated millions of years ago and which to-day are used for industrial and agricultural purposes. In a similar way, mention may be made of deposits of iron ore, gypsum, or limestone, in the formation of which bacteria played an important part.

To-day, like many millions of years ago, bacteria are busy creating conditions necessary for the growth of plants and animals. Bacteria are responsible for the circulation of carbon and nitrogen in nature. The material of plant and animal bodies is used over and over again, and processes of decay must go on in order that the carbon, nitrogen, sulphur, phosphorus, lime and other elements locked up in the bodies of plants and animals may be released for the development of countless generations of living things. It has been truly said that we may have in our bodies to-day the carbon, or the nitrogen, which were once in the bodies of the kings of Egypt or of living organisms of whose origin and history we know nothing.

After the lowly bacteria and other microscopic forms of life had lived and produced extensive changes on land and in the sea, conditions became more favorable for the growth of plants. The primitive forms of plant life gradually developed into more perfect organisms, until the mosses, ferns, cycads gave way to flowering plants, perhaps ten million years ago at a very conservative estimate. In some way bacteria learned to establish a partnership with some kinds of plants, such as clover, alfalfa, soy beans, etc. These plants, together with the bacteria, are the important factors in our agriculture as regards the maintenance of a supply of nitrogen in our soils.

Thus plants had to develop both as to quantity and quality in order that there might be sufficient food for the advancing forms of animal life. One may properly speak of the genesis and evolution of soil as one would speak of the genesis and evolution of plants and animals. Man has learned to use this knowledge to improve his condition, and in following the laws laid down by the Divine Creator,

he has been able to fashion more perfect forms of plant and animal life. The story of genetics, which deals with the principles of plant and animal breeding, is full of interest. It has to its credit more perfect flowers, fruit of higher yielding qualities and better flavor, fiber crops of superior fiber, sugar crops with a higher content of sugar, crops resistant to plant diseases, crops suitable for dry climates and wet climates, for sour soils and sweet soils, and, in general, for a wide range of soil and climatic conditions. In the same way, genetics has made it possible for us to improve on the types of animals of economic importance in our farming industry.

We are indebted to science for a clearer vision of the great laws of nature and of the methods of the Divine Creator. The men of science, in carrying on their labors in a spirit of reverence and humility, try to interpret the great book of knowledge, in order that the paths of man may fall in more pleasant places and the ways of human society may be in better keeping with the Divine purpose.

With these facts and interpretations of organic evolution left out, the agricultural colleges and experiment stations could not render effective service to our great agricultural industry.

GEOLOGY AND EVOLUTION

By WILBUR A. NELSON

STATE GEOLOGIST OF TENNESSEE, ELECTED CORCORAN PROFESSOR OF GEOLOGY AND HEAD OF THE DEPARTMENT OF GEOLOGY, UNIVERSITY OF VIRGINIA, AND STATE GEOLOGIST OF VIRGINIA

THE different layers of rock which form the surface of the earth unfold a remarkable story of evolution. These rock layers may be read as clearly as the leaves of a book, and they are the book which tells the true history of the earth; and the buried remains of animal and plant life which they contain likewise show the rise of life and its development on this earth. All forms of life have changed and developed to meet the conditions which have existed on the earth, as it has developed to meet the conditions which have been developing from the beginning of geological time.

Tennessee is an ideal place in which to study and learn the story of the rock layers which have been laid down, from the earliest times in which any life existed up to the present. Life forms suitable for one period of the earth's history proved unsuitable for another period, and so new forms, therefore, evolved through natural causes.

This is not a new study in Tennessee, as geology and its study of buried animal and plant remains has been taught in this state since 1828, at which time Gerard Troost, one of the founders of the Philadelphia Academy of Science, was elected professor of geology at the University of Nashville, and three years later was elected state geologist of Tennessee. From that date to the present time, this science, dealing with the age and study of the earth, and its rocks and the buried life which they contain, has been continuously taught in Tennessee.

Such teaching could not have been carried on through ninety-seven years of time, unless the teaching of evolution had been permitted as it was permitted by our religious ancestors who formed this state.

We know that streams and rivers carry sediment; that muddy waters are full of the soil of some field, washed into a nearby stream by a hard rain, and some such soil, when it once gets into a stream, starts on a long journey to the ocean. Most of the streams in this section are muddy for many months in each year, and this mud, which is the soil washed from our gullied hillsides, in this particular case, goes down the Tennessee River, into the Mississippi River and to the Gulf of Mexico.

We know that at the mouth of the Mississippi River the sediments brought down by this river are deposited so rapidly that land is formed which is extending out into the Gulf of Mexico at the rate of many feet a year. As a rule, these processes of weathering of rocks to produce soil, of erosion of this soil and of deposition of this transported soil through rivers into some nearby sea or ocean, takes place so slowly, as time is generally measured, that we can only see through detailed and scientific observation the results within our own lifetime. But at the delta of the Mississippi River this very process is taking place so rapidly that any one can easily measure it year by year and can understand that these same processes have been taking place through all geologic time, and in each and every part of the world.

We also know that practically all the earth has at some time or other been covered by water and in these ancient seas life has existed, which has left its record to us in fossil form. It must, however, also be understood that large parts of our present water areas were at some period in past geologic time also land areas. These seas have come and gone over limited areas of the earth's surface many times during the geologic history of the earth.

We know that originally the mouth of the Mississippi River was near Cairo, Illinois, and that all the Mississippi Valley, as we now know it, was at that time (which was the close of the Cretaceous

Period) a part of a much larger Gulf of Mexico than the one that now exists. All West Tennessee, during this time, was in a northern extension of the Gulf of Mexico, and the fine china clay deposits of that section were laid down in shallow water at the time tropical plants flourished in that section.

East Tennessee is made up of many layers of rocks, limestone, shale and sandstone, all of which were likewise laid down under water, and many of these layers contain the remains of animal and plant life. Some of the oldest rocks which contain animal life are found in East Tennessee. They are known as Cambrian rocks, and in these rocks occur the first abundant remains of sea form of life. This was the age of the early invertebrates. These rocks are well exposed to the east of Dayton in the East Tennessee Valley region.

Then came the time interval which the geologist calls the Ordovician, the time when primitive fishes, corals and land plants came into existence. Some of these first corals in fossil form have been found in the western edge of Dayton. This time interval was followed by another series of rocks which, in East Tennessee, contain the red iron ore deposits which are used by the iron furnaces of this section. The rocks of this age are known as the Silurian, and during this time life further developed and scorpions and lung fishes came into existence.

The series goes on. Layer after layer of rocks were laid down, each series of which has been given a name by geologists so that they can be easily referred to. Next came the Great Age of Fishes, and their remains are found in the rocks which the geologists call the Devonian and Mississippian series. The black slate, which crops out at the foot of Waldens Ridge, as well as the limestones lying above it, which form the side of the mountain to the west of Dayton, are layers belonging to these series. These rocks are full of the remains of animal life.

Then came the period in which the ancient plants flourished and produced great coal deposits, the age which has been called the Carboniferous. The extensive coal deposits of the Tennessee coal field, the edge of which caps the mountain a few miles west of Dayton, are of this age, and wonderfully preserved plant remains are found in the slates which lie on top of the different coal seams. This is a fact well known by the coal miners of this section. And what has been stated above as to Tennessee is but one illustration of how the different geologic periods passed and life developed over the earth.

And even when this Carboniferous period in the development of the earth has been reached, we are still many millions of years back from the age of man. We must still pass through many

geological time periods, through that age known as the Permian, when land vertebrates first arose, through the Triassic, when reptilian mammals arose, through the Jurassic, when flying reptiles were in existence. This was the Age of Reptiles. Then into the Cretaceous, when flowering plants came into existence, and a great group of the reptiles known as dinosaurs became extinct.

And then we come to that period in the earth's history, at the beginning of which the ancient mammals and birds were first known to exist. Fossil remains show clearly that birds evolved from flying reptiles. This is the Great Age of Mammals. Through this period the modern life forms developed. A period of glacial activity took place, during which five distinct glacial stages existed, one after the other, with four interglacial intervals, and man-like beings came into being at least at the beginning of this time. Such, very briefly, is an account of the evolution of the earth from Cambrian time to the present, with a brief outline of the life forms which existed during these different periods. We know that this took many millions of years, and yet we also know that the earth existed untold millions of years before Cambrian time.

For the formation of the earth and its early stages we must turn to the science of astronomy. The relations of the earth to the stars and the planets are shown in the depths of the heavens, and there must exist in the heavens those cosmic conditions which gave rise to our world and the other planets of our system. Through the telescope and spectroscope the astronomers have solved many of these secrets.

But what of the age of the earth measured in years as we measure other happenings? From the brief outline just given one can see that it has been in existence unknown millions of years, but just how many it is impossible to say.

We can, however, measure back to the more recent events in geological time to the last ice age, before which we know man existed, and get a fairly accurate result, in terms of years Geologists from the scientific studies they have made have reached the conclusion that from the present time back to the close of the glacial state known as the Wisconsin, the period of the last ice stage, the time interval is between twenty-two thousand and thirty-five thousand years, and man is known to have existed before this time.

One of the most accurate ways in which to measure such time intervals is by measuring and counting the light-colored and dark-colored bands of clay, deposited by the melting of the ice sheet in the fresh water lakes which existed on the edge of those continental glaciers as it retreated to its present position in the north polar regions. Each dark layer of clay was laid down during one winter

and each light layer during one summer. By such detailed studies, it has been determined that it has taken, approximately, 5,000 years for the glaciers of Sweden to melt back 270 miles, and it is further known that this melting back took place 8,500 years ago. We know that the glaciers in North America extended into the northern part of the United States and reached as far south as the Ohio River. We know that now their southern edge lies far to the north in Northern Canada over a thousand miles away. We know that it took approximately 4,000 years for the continental glacier which last covered the New England States to melt back from Hartford, Connecticut, to St. Johnsbury, Vermont. This is only one way of measuring in years some of the more recent geological happenings. There are many other methods that could be given if it were necessary.

In connection with evolution, it is especially of interest to note that the relative ages of the rocks correspond closely to the degrees of complexity of organization shown by the fossils in these rocks. The simpler organisms being found in the more ancient rocks, each type of organism becomes more and more complex as we come nearer to the present day, man and his fossil and cultural remains being no exception.

It, therefore, appears that it would be impossible to study or teach geology in Tennessee or elsewhere without using the theory of evolution.

EVOLUTION AND MENTAL LIFE

By Dr. CHARLES HUBBARD JUDD

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IN the normal schools of the state of Tennessee it will, I think, be impossible to obey the law without seriously depriving teachers in training of a proper view of the facts of human mental development. Every psychologist recognizes the fact that the human organs of sense such as the eye and the ear are similar in structure and action to the organs of sense and of the animals. The fundamental pattern of the human brain is the same as that of the higher animals. The laws of learning which have been studied in psychological and education laboratories are shown to be in many respects identical and always similar for animals and man. It is quite impossible to make any adequate study of the mental development of children without taking into account the facts that have been learned from the study of comparative or animal psychology.

It will be impossible in my judgment in the state university as well as in the normal schools to teach adequately psychology or the science of education without making constant reference to all the facts of mental development which are included in the general doctrine of evolution. The only dispute in the field of psychology that has ever arisen among psychologists so far as I know has to do with the methods of evolution. There is general agreement that evolution in some form or other must be accepted as the explanation of human mental life.

Elaborate studies have been made in the field of human psychology dealing with such matters as the evolution of tools, the evolution of language and the evolution of customs and laws. All these studies are based on definitely ascertainable facts and show without exception that a long process of evolution has been going on in the life of man as it is definitely known through historical record and prehistoric remains. In my judgment it will be quite impossible to carry on the work in most of the departments in the higher institutions of the state of Tennessee without teaching the doctrine of evolution as the fundamental basis for the understanding of all human institutions.

Whatever may be the constitutional rights of legislatures to prescribe the general course of study of public schools it will in my judgment be a serious national disaster if the attempt is successful to determine the details to be taught in the schools through the vote of legislatures rather than as a result of scientific investigation.

THE EVOLUTION OF MAN

By Dr. FAY-COOPER COLE

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ANTHROPOLOGISTS accept evolution as the most satisfactory explanation of the observed facts relating to the universe, to our world and all life on it. They hold that the evidence abundantly justifies us in believing that development has been from the simple to the complex and that present forms of life, including man, have been produced from earlier existing forms, but through immense periods of time.

The field of the anthropologist is man, man's body and man's society, and in this study he finds himself working side by side with the biologist and the geologist. For the study of man's body he has worked out a set of instruments and has selected a series of points for observation, by means of which he can accurately describe each

individual of a group, the length, breadth and height of head, the facial proportions, the length of limbs and so on.

In this way the anthropologist determines the average of a group or tribe or race, and to determine its normal variation. Anything strikingly beyond the normal at once becomes the subject of inquiry to determine its cause. In addition to the mathematical description there are added observations—color of skin, shape of teeth, the form of the hair and many others.

On man's skeleton these observations are even more exact and are so definite that given a single skull or skeleton it is possible to tell with considerable certainty the age, sex and race of the individual, while for a series of skeletons the results are definite. The skeletons tell much of man's history, for the articulation of the bones and the lines of attachment of the muscles reveal how he walked, how he held his head and many other details of his life. It also reveals the fact that man presents many variations difficult to explain without referring to similar conditions found in the animal world. To gain further light on these variations the anthropologist works with the anatomist and comparative anatomist and he quickly finds that every human being of to-day possesses many muscles for which there is no apparent use, such muscles as those behind the ears, those going to the tail, the platysma—a muscle going from the chin to the clavicle. These are but a few among many which to-day are functionless in man, but are still in use by certain animals. Going to the human embryo we find these vestiges of an earlier condition much more developed, while others appear for a time and then vanish before birth. Such a case is the free tail possessed by every human embryo a few weeks before its birth.

It is difficult to explain the presence of these useless organs in man unless we believe that some time in his development they were in use.

This study also reveals the fact that man closely resembles certain members of the animal world in every bone and organ of his body. There are differences, but they are differences of degree rather than of kind. Those animals most closely resembling man are the anthropoid apes. A careful study shows that they have specialized in their way quite as much as man has in his, so that while they are very similar, yet it is evidence that man's line of descent is not through any of these anthropoids. It does appear, however, that both man and the other primates have a common precursor, but that the anthropoids must have branched off from the common stock in very remote times. If this is true, then we might hope to find in ancient strata of the rocks some evidences of earlier forms of men, who might perhaps more closely approach the common an-

cestor. This is exactly the case. The geologists have established the relative age of the strata of the rocks, while the paleontologists have made plain the forms of life which lived in the epochs when these strata were deposited.

In the strata laid down at the end of the Pliocene period at least 500,000 years ago, there have been found the bones of a being which appears to be an attempt of nature toward man. In the year 1891, on the island of Java, there were found the bones of an animal which in many ways seems to be intermediate between man and the anthropoids. These bones were found in undisturbed strata forty feet below the surface, at a point where a river had cut through the mountain side. There can be no doubt that these bones were laid down at the time that the stratum was deposited and by studying the associated fauna, consisting of many extinct animals, the age of these rocks is established. These bones were not lying together, but had been scattered over a distance of about forty-five feet by the action of the ancient river which deposited them.

These semi-human bones consisted of a skull cap, a femur and two molar teeth. The skull was low with narrow receding forehead and heavy ridges of bone above the eye-sockets, while a bony ridge extended from between the eyebrows to the top of the head approaching a condition found in the cranium of the anthropoids. The brain capacity of this individual was between 850 and 900 cubic centimeters, or a little more than half of that of modern man. On the other hand, it is half as much again as that of an adult gorilla, and the special development has taken place in those regions whose high development is typical of the brain of man. Hence in this respect this being seems to stand midway between man and the highest anthropoids. The teeth approach the human type and indicate the peculiar rotary mode of mastication of the human which is impossible in animals having interlocking canine teeth. The thigh bone is straight, indicating an upright posture and ability to run and walk, as in man. And the muscle attachments show he was a terrestrial and not an arboreal form. If, as seems probable, these four bones belonged to the same individual, he must have been more man-like than any living ape and at the same time more apelike than any human known to us. He is known as Pithecanthropus erectus or the erect ape man.

Another find of somewhat similar nature was made only a few months ago in Bechuanaland of South Africa by Professor Dart, of the University of Johannesburg. This find consisted of the skull of an animal well developed beyond modern anthropoids in just those characters, facial and cerebral, which are to be expected in a form intermediate between man and the anthropoids. Neither of

these two beings are, of certainty, directly ancestral to man, but they do seem to indicate that nature at a very early period was making experiments toward man.

Two other fossil beings, found in the early strata of the rocks, also seem to indicate a development toward man. In the strata of the second interglacial period, probably at least 250,000 years ago, there lived a being with a massive jaw, a jaw human in every respect, except that it had no chin and the ramus or upright portion toward the socket was very broad, as in the anthropoids. This jaw is so narrow behind that it is thought the tongue could not have sufficient play to allow of articulate speech. The teeth, although very large, are essentially human with even tops, as in man, while the canines lacked the tusk-like character which they still retain in the apes. This jaw was found in the year 1907 in a sand-pit working near Heidelberg, Germany. It was discovered in place at a depth of nearly eighty feet and lay in association with fossil remains of extinct animals which make possible its dating in geologic time. It is difficult to picture a man from the jaw alone, but this much we can say, the mouth must have projected more than in modern man but less than in the chimpanzee or gorilla. He had a heavy protruding face, huge muscles of mastication, essentially human teeth and he was already far removed from his primate ancestors with large canines; he was nearer to man than to the apes; he was further along the line of evolutionary development than Pithecanthropus erectus, the Java Ape-man, and he lived at a much later period. This being is known as the Heidelberg man.

The second of these two finds which we have mentioned occurred near Piltdown, in Sussex, England. This consisted of the crushed skull of a woman and a jaw which can scarcely be distinguished from that of a chimpanzee. For a time there was much question if the two could possibly belong together, but a more recent find, which occurred about three miles distant from the first, again showed portions of the same type of skull and jaw. The skull is exceedingly thick and its capacity much less than that of modern man, but it is distinctly human, while, as indicated, the jaw approaches that of an anthropoid. Here again we seem to have an approach toward man in very ancient strata.

Toward the end of the second interglacial period in Europe, at least two hundred and twenty-five thousand years ago, we begin to find stone implements which give indication of having been intentionally formed and used by intelligent beings. By the third interglacial period, more than one hundred and fifty thousand years ago, these utensils have taken on definite form and we find thousands of stone axes of crude type scattered over a large portion of central and

southern Europe. We have no fossil remains of man during this third interglacial period, for he then lived in the open and it would not only be by the merest chance that his skeletons might be preserved to us. But when the fourth glacial epoch spread over Europe these men were compelled to make their homes in the shelters and caves of the rocks, and here in the débris around their ancient hearths we can read the record of their home life, and from this period on for a period of at least 50,000 years we can read the record of man's occupancy of Europe as clearly as though we were reading from the pages of a book. Fortunately for the scientists, these people buried their dead and we have preserved for us a considerable number, ranging from children to adult men and women, so there is no guessing as to the sort of man who occupied Europe at this time.

They were massively built, with long arms and short legs, in height they averaged about five feet three for the men and four feet ten for the women or about the same as the modern Japanese. The head was long and narrow; above the eyes was a heavy bony ridge, back of which the forehead retreated abruptly, indicating rather little development of the forebrain. The nose was low and broad, the upper lip projecting, but the jaw was weak and retreating. The head hung forward on a massive chest; this we know because the foramen magnum, the opening by which the spinal cord enters the cranium, was situated further back than is the case in modern man, and the points of articulation with the bones of the neck also show conclusively that the head hung habitually forward. In all cases we find the thigh bone to be curved and this, together with the points of articulation, show that the knee was habitually bent and that this man walked in a semi-erect position. These people, known as the Neandertal race, spread out over the western half of Europe and we now know and have excavated very large numbers of the stations in which they lived. They were men—they were human—but they were much more like the anthropoids in many respects than is modern man. They lived in Europe for a period of at least 25,000 years, probably much longer, when they were displaced by newcomers who pushed in from around the eastern end of the Mediterranean and from Asia. The newcomers, known as Cro-magnon, are a much finer physical type but so closely related to modern man that it is not necessary to describe their physical type; but it is of interest that we can study his home life, his art and his life among certain animals now extinct for a period beginning about 20,000 years ago, and extending down to the coming of the modern races.

Only a few points relating to man and his history have been reviewed, but enough has been said to indicate that the testimony

of man's body, of his embryological life, of his fossil remains strongly points to the fact that he is closely related to the other members of the animal world, and that his development to his present form has taken place through immense periods of time.

From the above it seems conclusive that it is impossible to teach anthropology or the prehistory of man without teaching evolution.

EVOLUTION AND RELIGION

By Dr. KIRTLEY F. MATHER

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Such facts as I have stated can be explained only by the conclusion that man has been formed through long processes of progressive development, which when traced backward through successively simpler types of life, each living in more remote antiquity, lead unerringly to a single primordial cell. The facts ascertained by natural science are obviously incomplete; the record of the rocks by no means tells the whole story. Man not only has an efficient and readily adaptable body, he also possesses a knowledge of moral law, a sense of rightness, a confidence that his reasoning mind finds response in a rational universe, and a hope that his spiritual aspirations will find increasing answer in a spiritual universe. Such things as these can not be preserved in the fossil record, yet their presence must be accounted for. Nor have we a direct record of whence came the first living cell. The inference is unmistakable that the material substances from which living cells were first constructed were previously present among the rocks and minerals of the earth. All the necessary ingredients were certainly present in the outer shell of the youthful earth of even pre-Archeozoic time. But life is something more than matter. Living creatures are characterized by vital energy, something about which we really know very little, but something which is absolutely indispensable to every living creature. T. C. Chamberlin, the dean of American geologists, closes his volume on the origin of the earth with the following sentence: "It is our personal view that what we conveniently regard as merely material is at the same time spiritual, that what we try to reduce to the mechanistic is at the same time volitional, but whether this be so or not, the emergence of what we call the living from the inorganic, and the emergence of what we call the psychic from the physiologic, were at once the transcendent and the transcendental features of the earth's evolution." With this conclusion I am in hearty accord. I believe that life as we know it is but one

manifestation of the mysterious spiritual powers which permeate the universe. The geologic factors assembled in the primitive earth provided an environment within which the spiritual could manifest itself in the material. The form which it should assume may have been largely determined by that environment; the primitive cell was the result. Thus, in truth, was man made from the dust of the ground.

Again, the record of the rocks tells nothing except by inference of the previous state of the mineral matter of which the earth is made. Several theories, varying from one another in greater or less detail, are now under consideration by geologists and astronomers in their attempt to understand the actual beginnings and the antecedents of the earth and its fellow planets in the solar system. So far as we now know all the planets, suns and stars within range of our telescopes are composed of the same sort of matter, reducible upon analysis to about eighty different elements, nearly all of which are present in the earth. In other words, it is a fair sample of the material substances of the entire universe. Science has not even a guess as to the original source or sources of matter. It deals with immediate causes and effects, not at all with ultimate causes and effects. For science there is no beginning and no ending; all acceptable theories of earth origin are theories of rejuvenation rather than of creation from nothing. Indeed, there is some evidence for the prevalent view that our sun had had at least one earlier generation of planets in its train before the disturbing effect of the close approach of another star caused the reorganization of part of its matter into our present solar system. Conversely, it is probable that at some remotely distant date in the future this group of planets, on one of which we live, will be similarly destroyed by another rejuvenating disturbance and still another cycle of planetary organization may take place.

But none of these facts is really in any way disturbing to the adherent to Christianity. Not one contradicts any teaching of Jesus Christ known to me. None of them could; for his teachings deal with moral law and spiritual realities. Natural science deals with physical laws and material realities. When men are offered their choice between science, with its confident and unanimous acceptance of the evolutionary principle, on the one hand, and religion, with its necessary appeal to things unseen and unprovable, on the other, they are much more likely to abandon religion than to abandon science. If such a choice is forced upon us, the churches will lose many of their best educated young people, the very ones upon whom they must depend for leadership in coming years. Fortunately, such a choice is absolutely unnecessary. To

say that one must choose between evolution and Christianity is exactly like telling the child as he starts for school that he must choose between spelling and arithmetic. Thorough knowledge of each is essential to success—both individual and racial—in life.

Although it is possible to construct a mechanistic evolutionary hypothesis which rules God out of the world, the theories of theistic evolution held by millions of scientifically trained Christian men and women lead inevitably to a better knowledge of God and a firmer faith in his effective presence in the world. For religion is founded on facts, even as is the evolutionary principle. A true religion faces the facts fearlessly, regardless of where or how the facts may be found. The theories of evolution commonly accepted in the scientific world do not deny any reasonable interpretation of the stories of divine creation as recorded in the Bible, rather they affirm that story and give it larger and more profound meaning. This, of course, depends upon what the Bible is and what the meaning and interpretation of the stories are to each individual. I have been a Bible student all my life, and ever since my college days I have been intensely concerned with the relations between science and the Bible. I have made many addresses and have written several articles upon this subject. I have many times lectured to Biblical students, such as those in the Boston University School of Religious Education.

It is obvious to any careful and intelligent reader of the book of Genesis that some interpretation of its account must be made by each individual. Very evidently, it is not intended to be a scientific statement of the order and method of creation. In the first chapter of Genesis we are told that man was made after the plants and the other animals had been formed, and that man and woman were both created on the same day; in the second chapter of Genesis we read that man was formed from the dust of the ground before plants and other animals were made, that trees grew until fruit was upon them, that all the animals passed in review before man to be named, and then after these events woman was made. There is obvious lack of harmony between those two Biblical accounts of creation so far as details of process and order of events are concerned; they are, however, in perfect accord in presenting the spiritual truth that God is the author and the administrator of the universe. And that is the sort of truth which we find in the Bible. It is a text-book of religion, not a text-book of biology or astronomy or geology. Moreover, it is just exactly the Biblical spiritual truth concerning God which rings clearly and unmistakably through every theory of theistic evolution. With it modern science is in perfect accord.

There are a number of reasons why sincere and honest Christians have recently come to distrust evolution. These reasons must be understood and discussed frankly before the world will believe that science and religion are not in conflict. Some of the opposition to evolutionary science results from failure to read the Bible. Too many people who loudly proclaim their allegiance to the Book know very little about what it really contains. The Bible does not state that the world was made about six thousand years ago. The date 4004 B. C., set opposite Genesis 1: 1 in many versions of the Bible, was placed there by Archbishop Ussher only a few centuries ago. It is a man's interpretation of the Bible; it is in the footnotes added recently. It is not a part of the book itself. Concerning the length of earth history and of human history the Bible is absolutely silent. Science may conclude that the earth is a hundred million or a hundred billion years old; the conclusion does not affect the Bible in the slightest degree. Or if one is worried over the progressive appearance of land, plants, animals and man on the successive six days of a "creation week," there is well-known Biblical support for the scientists' contention that eons rather than hours elapsed while these things were taking place. "A day in the sight of the Lord is as a thousand years, and a thousand years as a day." Taking the Bible itself as an authority dissipates many of the difficulties which threaten to make a gulf between religion and science. The fact that the seventh day was stated to be a day of rest has no bearing upon the length of the other days. I have no doubt that the man who made that chapter of Genesis had in his mind days of twenty-four hours each, but I reserve for myself the right to make my own interpretation of the meaning of words, as does every Christian, be he liberalist, trivialist or modernist.

Another of the reasons for the modern distrust of science in the religious world is the idea that evolution displaces God. Many seem to think that when the scientist enthrones evolution as the guiding principle in nature he dethrones God, that the two words are somehow synonymous, that there is not room for both and one must go. But the facts are as follows: Evolution is not a power, nor a force; it is a process, a method. God is a power, a force; he necessarily uses processes and methods in displaying his power and exerting force. Many of us believe that science is truly discovering in evolution the processes and the methods which God, the spiritual power and eternal force, has used and is using now to effect his will in nature. We believe we have a more accurate and a more deeply significant knowledge of our Maker to-day than had the Hebrew patriarchs who thought a man could hide from God in a garden or who believed that God could tell man an untruth. (Gene-

sis 2: 17 states that God told man he would surely die if he ate the fruit of the tree of knowledge; man ate, he did not die, God knew he would not die therefore.)

Again there is the widespread misconception that if one accepts the evolutionary process as the method which God used, he will find himself in a moral dilemma. Regardless of sect or creed, all followers of Christ must accept his teaching that the law of life is love, that service to others is the true guiding principle, that self-sacrifice even to death is the best trait a man can display. To many evolution means the survival of the fittest in the struggle for existence; and that is taken to imply that the selfish triumph, the most cruel and bloodthirsty are exalted, those who disregard others win. Obviously this is the very antithesis of Christianity; both principles can not be true; one must be false. The Christian needs not to be told which of the two it is. Here is a real reason for opposition to evolution; men are not driven from it by the fear of discovering that their bodies are structurally like those of apes and monkeys; it doesn't bother us to discover that we are mammals, even *odorous* mammals—"by the sweat of his brow must man earn food," states the Bible. It *does* bother us to find the implication that the law of progress has thus apparently been opposed to the love of Christ. But here are the facts. It has been my privilege as a geologist to read the record in the rocks; knowing the ages of the rocks has led to better knowledge of the Rock of Ages; I have watched the procession of life on the long road from the one-celled bit of primitive protoplasm to the present assemblage of varied creatures including man. At times of crisis in the past it was rarely selfishness or cruelty or strength of talon and of claw that determined success or failure. Survival values at different times have been measured in different terms. Ability to breathe air by means of lungs rather than to purify the blood by means of gills meant success in escaping from the water to the land. Love of offspring and tender care for the young gave the weak and puny mammals of long ago the ability to triumph over much stronger and more powerful reptiles like the dinosaur. Especially in the strain that leads to man can we note the increasing spread of habits of cooperation, of unselfishness, of love. The survival of the "fit" does not necessarily mean either the survival of the "fittest" or of the "fightingest." It has meant in the past, and I believe it means to-day and to-morrow, the survival of those who serve others most unselfishly. Even in evolution is it true that he who would save his life must lose it. Here, if nowhere else, do the facts of evolution lead the man of science to stand shoulder to shoulder with the man of religion.

Another difficulty arises from our present limitations of knowledge. If man has evolved from other forms of animal life by the continuous process of evolution it is asked how can there be any difference between him and them, how can we believe that he has an immortal soul. Again, the appeal to facts makes it clear that somehow out of the continuity of process real differences have emerged. When the cow pauses on the hillside to admire the view, when the dog ceases to bay at the moon in order to construct a system of astronomy, then and not till then will we believe that there are no differences between man and other animals. Even though we may not understand how these differences arose, the facts are there; knowledge and mystery exist side by side; mystery does not invalidate the fact. Men of science are working on those very problems. They have not learned—and may never learn—how God breathed a living soul into man's body. If they should discover that process and the method used, God will still be just as great a power. In the image of God can not refer to hands or feet, heart, stomach, lungs. That may have been the conception of Moses, it certainly was not the conception of Christ who said that God is spirit and proclaimed that man must worship Him in truth. It is man's soul, his spirit, which is patterned after God the Spirit.

It is the business of the theologian, not the scientist, to state just when and how man gained a soul. The man of science is keenly interested in the matter, but he should not be blamed if he can not answer questions here. The theologian must tell when the individual gets his soul, whether at the moment of conception or when the unborn babe first stirs within the womb or at the moment of birth or at the first gleam of intelligent appraisal of his environment and how he knows this.

Men of science have as their aim the discovery of facts. They seek with open eyes, willing to recognize it, as Huxley said, even if "it sears the eye-balls." After they have discovered truth, and not till then, do they consider what its moral implications may be. Thus far, and presumably always, truth when found is also found to be right, in the moral sense of the word. Men of religion seek righteousness; finding it they also find truth. The farther along the two avenues of investigation the scientist and the theologian go, the closer together they discover themselves to be. Already many of them are marching shoulder to shoulder in their endeavor to combine a trained and reasoning mind with a faithful and loving heart in every human individual and thus to develop more perfectly in mankind the image of God. Neither the right kind of mind nor the right kind of heart will suffice without the other. Both are needed if civilization is to be saved.

As Henry Ward Beecher said, forty years ago, "If to reject God's revelation of the Book is infidelity, what is it to reject God's revelation of himself in the structure of the whole globe?" With that learned preacher men of science agree when he stated that "the theory of evolution is the working theory of every department of physical science all over the world. Withdraw this theory and every department of physical research would fall back into heaps of hopelessly dislocated facts, with no more order or reason or philosophical coherence than exists in a basket of marbles, or in the juxtaposition of the multitudinous sands of the seashore. We should go back into chaos if we took out of the laboratories, out of the dissecting rooms, out of the field of investigation, this great doctrine of evolution." Chaos would inevitably destroy the whole moral fabric of society as well as impede the physical progress of humankind.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

A CRAZY EXPERIMENT

I SUPPOSE every scientific man occasionally tries experiments that he would not care to confess to his colleagues. Crazy ideas will pop up in the best regulated brains from some subconscious cellar and sometimes they are tried out, on Saturday afternoon when there is nobody else around, just to see what will come of them. They do not appear in the published reports, unless they happen to succeed, in which case the audacious experimenter will claim credit for foresight in undertaking an operation that ordinary minds would have condemned in advance as absurd.

Now it is interesting to observe that such erratic and irrational experimentation is distinctly recommended by the philosopher who laid down the laws of experimental science that have in the three centuries since accomplished such amazing achievements.

Lord Bacon, after listing in his precise and orderly manner all the various ways that we may be guided in our researches by theory, observation and previous experiment, concludes quite unexpectedly by adding a new category, what he calls the experiments of a madman and defines as follows:

"When you have in mind to try something not because reason or some other experiment leads you to it but simply because such a thing has never been attempted before."

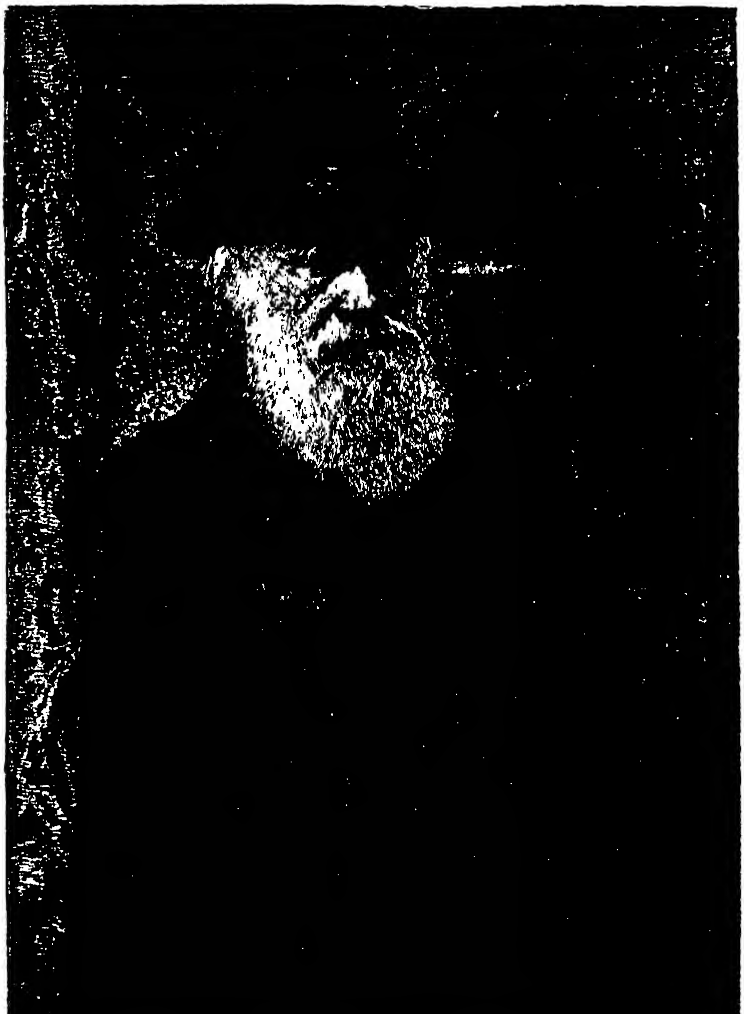
"The leaving I say, of no stone in nature unturned, for the magnalia of nature generally lie out of the common roads and beaten paths so that the very absurdity of the thing may sometimes prove of service. But if reason go along with it, that is, if it be evident that an experiment of this nature has never been tried, then it is one of the best ways and plainly shakes the folds out of nature."

The example Bacon gives of such unprecedented experiments is of peculiar interest to us:

"But of what I may call close distillation no man has yet made trial. Yet it seems probable that the force of heat, if it can perform its exploits of alteration within the enclosure of the body, where there is neither loss of the body not yet means of escape, will succeed at last in handcuffing this Proteus of matter and driving it to many transformations; only the heat must be so regulated and varied that there be no fracture of the vessels.

"No one should be disheartened or confounded if the experiments which he tries do not answer his expectation. For though a successful experiment be more agreeable, yet an unsuccessful one is often times no less instructive. And it must ever be kept in mind (as I am continually urging) that experiments of Light are even more to be sought after than experiments of Fruit."

What Bacon was "continually urging" that "experiments of Light"—those that lead to the enlightenment on fundamental principles—"are even



Ch. Darwin

more to be sought after than experiments of Fruit"—those that bring practical results—needs more than ever to be kept in mind at the present day when public and employers are impatient of research that does not bring immediate and profitable returns.

So it is worthy of notice that the example that Bacon cites, as the experiment of a madman, that is, destructive distillation, has been peculiarly productive of both light and fruit. Applied to coal it has given us coke for metallurgy, gas for cities, and shops and coal tar products of innumerable variety and inestimable value. Applied to petroleum in the cracking process it has increased the yield of gasoline by some 2,000,000 gallons a day. By this "handcuffing this Proteus of matter and driving it to many transformations" Light has been thrown upon the structure of the molecule and the chemistry of life.

TAKE YOUR VITAMINS IN FOOD

"VITAMINS should be sought in the garden, or in the market, and not in the drug store," says Dr. D. Breese Jones, chemist in charge of Protein Investigations of the Bureau of Chemistry, of the Department of Agriculture, in a recent report giving a summary of our present knowledge of vitamins. "In cases of suspected vitamin deficiency in the diet," according to the report, "corrective measures should be taken through the use of suitable natural foodstuffs, and not through commercial vitamin preparations, many, if not most of which are worthless."

Vitamins play a very different rôle in nutrition from the other food constituents. They are essential to growth, health and life, but they contribute neither energy nor tissue building material. Their function has been likened to that of the spark plug in a gas engine. They are often referred to as the accessory food factors.

People and animals are unable to provide vitamins within their bodies. Lack of sufficient vitamins in the diet is soon followed by serious consequences. Young animals will fail to grow normally, and adults will rapidly decline in weight and develop certain characteristic affections known as deficiency diseases.

It is now known that there are at least five vitamins, designated as A, B, C, D and E, and it is probable that others will be discovered. The absence from the diet of any one of the five will produce certain characteristic effects.

Vitamin A, for instance, is essential to growth and health. Young animals on a diet devoid of it soon stop growing and lose weight. Their vitality becomes lowered and they are less able to resist disease and infection, particularly of the respiratory tract. In many animals, as rats, dogs, rabbits and poultry, and also in man, a characteristic affliction of the eyes results. The administration of Vitamin A prevents or promptly cures this affliction. Growing animals require more of it than do adults. It is abundant in butter, cream, cheese, whole milk, egg yolk, the liver, heart and kidneys of animals, in spinach, lettuce, cabbage, tomatoes, carrots, sweet potatoes, parsnips and green peas, and is present in varying quantities in many other foods. Cod liver oil is rich in this vitamin and the liver oils of some other varieties of fish contain it.

Vitamin B is also necessary for the maintenance of life and health at all ages. Lack of it promptly results in loss of appetite and arrest of growth, followed by various functional disorders and, finally, death. This

Wide World Photos

MME. PIERRE CURIE

Professor of general physics and director of the Curie Laboratory of the Radium Institute of the University of Paris, addressing a scientific meeting at the university.

DR. FLORENCE R. SABIN

Since 1903 connected with the department of anatomy of the Johns Hopkins University, who has become a member of the Rockefeller Institute for Medical Research, New York City. Dr. Sabin was this year elected a member of the National Academy of Sciences, this being the first time the honor has been conferred on a woman.

is the most widely distributed of all the vitamins. It is abundant in green plant tissues. Cereals and seeds contain it, the germ of the seed being an exceptionally good source. Yeast and wheat germ are standard sources of this vitamin in experimental work. Roots and tubers as a class are good sources of it, and it is especially abundant in tomatoes. Most fruits and nuts are well supplied with it. Meat is reported to contain Vitamin B. The heart appears to be the richest in this vitamin, and the liver and kidneys have only slightly lower values. The flesh of the chicken, turkey, duck and guinea fowl, however, are deficient in it.

Notwithstanding the wide distribution of vitamin B in foodstuffs, certain classes of people, as soldiers, sailors, travelers, infants and others, living on restricted or artificial diets, have suffered serious consequences because of a lack of it. Beriberi, one of the diseases produced by the absence of this vitamin, is most commonly found among those living chiefly on polished rice. Removal of the germ and seed coats or bran of cereals

takes away practically all the vitamins. Consequently, polished rice, patent white flour, and degerminated corn meal are practically devoid of vitamins.

Vitamin C is sometimes known as the "anti-scurvy vitamin," because a lack of it in the diet causes scurvy, a disease which has been prevalent among sailors, soldiers, explorers and others compelled to live for long periods on dried and preserved foods.

Even in the late World War, Wilcox states, there were more than 11,000 cases of scurvy in the British colonial troops in Mesopotamia during the last half of 1916. Farm animals are not very susceptible to scurvy and it is considered that chickens and pigs are not harmed by a lack of Vitamin C in their diet. The best sources of Vitamin C are lemons, oranges, tomatoes, cabbage, lettuce, spinach, green beans and peas, and turnips. Most green vegetables, fruits, roots and tubers contain Vitamin C in varying quantities. Meat, excepting the internal organs, is a poor source. It has been reported that oysters contain it in abundance. Milk contains it to some extent, but is an uncertain source. This vitamin is easily destroyed by the processes used in the preparation of many food products. Orange juice or tomato juice is sometimes given to babies reared on artificially prepared food as a precaution against scurvy.

Vitamin D seems to control to a large extent the utilization of lime and phosphorus in the formation of bone by the animal organism. Its absence in the diet will cause rickets, a disease characterized by enlargement of the joints, softening of the bones and subsequent bending. Hess states that "Rickets is the most common nutritional disease occurring among children of the temperate zone, fully three fourths of the infants in the great cities, such as New York, show rachitic signs in some degree." This disease can be prevented by a proper diet. It can also be prevented or cured by administering cod liver oil, which contains vitamin D in abundance, or by exposure to the ultra-violet rays of sunlight or the mercury lamp, if the diet contains the other necessary food elements in adequate quantity. This vitamin has been found in egg yolk and to some extent in milk. Coconut oil contains it in slight amount. As yet but little has been learned of the general distribution of Vitamin D in the plant world.

Vitamin E, the anti-sterility vitamin, was originally referred to as Vitamin X, because of the uncertainty as to whether or not it should be classed as a vitamin. Most of the knowledge concerning it has been obtained within the last two years. It has been shown that rats reared on synthetic food mixtures containing fat, carbohydrate, protein, salts and Vitamins A and B, grow well and have every appearance of health, but exhibit complete sterility, affecting both males and females. When small quantities of natural food stuff were added to the ration of these same rats, there resulted in many cases normal sized litters of vigorous young. An excess of Vitamin E can not increase fertility beyond normal limits.

ANEMIA

THE discovery of anemia or pale blood in laboratory animals that is "quite identical with a similar condition that occurs in man," after removal of the stomach, and new data that may lead to the prevention and cure of the condition have resulted from an important experiment in the physiology department of the University of Chicago conducted by Dr. A. C. Ivy and his assistants and made public recently.

International News Reel Photos

MESA VERDE CLIFF DWELLINGS

The largest of the prehistoric ruins in Southwestern Colorado.

Dr. Ivy and his colleagues completely removed the stomach from experimental animals and joined the small intestine to the esophagus or gullet so that food when swallowed entered the small intestine directly. They found that dogs can grow fat and live happily for months on a specially prepared diet of cooked ground meat, bread and milk.

Finally an anemia developed that is said to be the same as that which causes the unnatural paleness of skin in anemic human beings. "It appears from this observation," according to a report on his work by Dr. Ivy, "that the stomach is in some way concerned with the metabolism of iron, a substance that is necessary for the normal functioning of the blood and tissues. Experiments are now being conducted to discover a means by which this anemia can be prevented and cured."

Additional facts illuminating the whole study of gastric secretion have resulted from this experiment. It has been found that the mechanical distension of the stomach by food is one of the causes of gastric secretion. The simple distension of the stomach with a toy balloon will cause the gastric glands to secrete, Dr. Ivy has shown.

Meat contains a substance which will excite the gastric glands when introduced into the stomach. Other foods contain very little if any of this stimulating substance. Fats inhibit or slow up gastric secretion. Partially or completely digested foods acting in the intestine cause the stomach to secrete its digestive juice.

Dr. Ivy and his assistants have been successful in transplanting a part of the stomach and pancreas under the skin in the same experiment. After a meal is eaten the transplanted stomach and pancreas secrete. According to Dr. Ivy, this shows that there is something in the blood after a meal is eaten that causes these organs to secrete digestive juices.

By using the transplanted stomach they have been able to show that during hunger some change occurs in the blood which causes the stomach to contract, resulting in the so-called hunger pains or pangs.

THE SCIENTIFIC MONTHLY

OCTOBER, 1925

THE INERTIA OF ENERGY[1]

By Dr. PAUL R. HEYL

BUREAU OF STANDARDS

RELATIVITY may stay or go; the quantum theory may quarrel with the undulatory theory until there is no more left of either of them than of the traditional Kilkenny cats; and the unscientific may scoff: "What are the latest conclusions of science? I have not seen the morning papers." Yet I think we may safely say that the twentieth century, young as it is, has made at least one permanent contribution of the first magnitude to physical science—the doctrine of the inertia of energy.

To call any concept of physics permanent in these iconoclastic days is perhaps unsafe; yet the case for the inertia of energy is a strong one. Radical though it may be, and subversive of established ideas, it comes nevertheless of an old and respected family. Because Einstein's name is connected with it, it is perhaps rather generally supposed that this doctrine is in some abstruse way a corollary of the theory of relativity and consequently to be regarded with suspicion by the conservative. Not so; nothing has a better right to the name classical. It traces its descent in direct line from Maxwell and Newton; its pedigree is unimpeachable; its arms display no bar sinister. If the theory of relativity also leads to this doctrine, so much the better for relativity; it gains strength rather than imparts it.

The eighteenth century, like all its predecessors, was materialistic in its attitude toward natural phenomena. The modern concept of energy was not recognized; forces of all kinds were regarded as properties of matter, just as gravitational force was regarded until Einstein declared it to be not a material property at all, but

[1] Published by permission of the director of the Bureau of Standards of the U. S. Department of Commerce.

a space property. By the introduction of the concept of energy and its elevation to a rank coequal with matter the nineteenth century made a notable departure from this traditional materialism. At the close of the century the two concepts, matter and energy, divided the province of physical science equally between them.

This joint sovereignty presented to the philosophic onlooker several curious features. In the first place, it was a coalition uniting views as extreme as any in the history of human government, for matter is certainly "material," and energy nothing if not immaterial. Moreover, matter had an established position, with a pedigree of centuries behind it; it had been recognized "always, everywhere and by all," while energy, when it first came into notice, had even been introduced as a state or condition of matter. Its enthronement as joint sovereign had come about by virtue of its executive ability, the power it had shown of correlating phenomena and reducing the hitherto independent and intractable to law and order. Similar ability was shown by Mexico's benevolent despot, President Diaz, when he enlisted the roving bandits as members of the rural police force. The conservative citizens of the domain of physics, while acknowledging the equal sovereignty of energy, always retained in their hearts a special feeling of respect for matter as the ultimate reality, the substance of things, whose existence permitted energy to be, and without which energy would be but an empty name.

This state of mind was rudely disturbed when Einstein announced that henceforth the tail was to wag the dog; that matter must be regarded merely as another aspect of that protean concept, energy; that there was a definite numerical equivalent relation between them. Just as 4.2×10^7 ergs of energy equal one calory of heat, so one gram of matter may disappear as such, giving rise to 9×10^{20} ergs of energy.

But how can matter disappear? What then becomes of the law of conservation of matter, established over a century ago by Lavoisier, and long regarded as a great and permanent contribution to science? And how can energy appear without a corresponding disappearance of energy elsewhere? What of the law of conservation of energy, which has, since its foundation, enjoyed an esteem equal to that accorded the law of conservation of matter?

The doctrine of inertia of energy declares unflinchingly that both laws are wrong; that matter may actually disappear as such and energy in equivalent quantity appear in its stead. In place of the two former laws we have one broader principle—the conservation of matter-energy.

But under what circumstances does matter disappear, and why has this strange fact never been shown by the many careful and ingenious experiments on gravitation carried out during the nineteenth century? The explanation lies in the very large coefficient in the relation between matter and energy, 9×10^{20}. Experiment is well-nigh hopeless before the twentieth power of ten. The coefficient for the mechanical equivalent of heat contains only the seventh power of ten, and this permits an experimental verification of the principle. This fact undoubtedly assisted the physicists of the mid-Victorian period in familiarizing themselves with the idea that work and heat were interconvertible—a concept as strange to the physicists of those days as the equivalence of matter and energy is to us of to-day. It is said that Poggendorff refused to publish Mayer's paper on the mechanical equivalent of heat. "Why," said he to the author, "if this be true, water could be warmed by shaking it!" To this Mayer for some time could find no reply. The answer came only when it was shown experimentally that such was indeed the case. There is no denying the difficulty of a concept as revolutionary as the annihilation of matter and the creation of energy; and unfortunately we can not verify the theoretical principle by experiment. This theory asserts that when a hot body cools off, emitting heat and light, it must lose a little of its mass. For example, a gram of water at 100° will have when cooled to zero a mass less than one gram by the mass-equivalent of the energy that has been radiated away. To calculate this we divide the 100 calories, or rather 4.2×10^{9} ergs, by 9×10^{20}, obtaining about 5×10^{-12} gram. Now even when dealing with masses of the order of a kilogram it is not possible at present to detect a difference less than one part in a billion (10^{9}).

The most vigorous chemical reaction known is that of the union of oxygen and hydrogen. In the formation of 18 grams of water about 69,000 calories or 3×10^{12} ergs of energy are liberated. This, on division by 9×10^{20}, gives us for the decrease in mass 3×10^{-9} gram, about one part in six billion.

In the case of energy liberated by radioactive bodies experiment is, at first sight, not quite so hopeless. One gram of radium in transforming into radium D (the first considerable stop-over in the series) would liberate about 130 calories per hour. This transformation is very slow, the average life of a radium atom being 2,600 years, or about 2×10^{7} hours. Hence the total energy liberated in the transformation of one gram of radium into radium D (and helium) will be about $130 \times 2 \times 10^{7} \times 4.2 \times 10^{7} = 1.1 \times 10^{17}$ ergs. Dividing by 9×10^{20} we obtain 1.2×10^{-4} gram, or about one part in 10,000.

But such an experiment is impracticable. Starting with a gram of radium, the total amount transformed in one year would be 0.4 mg, and the actual loss in weight (of radium and helium together) only 5×10^{-8} gram. And to ensure that there is no error introduced by leakage (helium in the form of alpha rays) the containing case of lead would have to be constructed with preposterously thick walls, reducing the proportional change of weight far below the detectable limit.

Passing to the astronomer's laboratory we obtain quantities which seem large enough indeed to measure. The total energy radiated by our sun per second is enormous. Converted into its mass equivalent it gives the rather surprising figure of 4 million tons per second. This is not so easy to detect as might appear, for so super-enormous is the sun's mass that he is good for this rate of expenditure for something like 10 million million years.

So it appears that our sun and all the other stars in the heavens are slowly dissolving into light. Strange and novel as this idea may appear, it is no new thing, for a strikingly similar doctrine was taught in the eighteenth century, based upon the then current materialistic corpuscular theory of light. The following quotation from Nicholson's "Natural Philosophy" (London: 1786) illustrates this point and incidentally shows to what heights of speculation men dared to go in those days.

> If the comets be habitable, they must be possessed by creatures very different from any we have been used to behold and consider. There may, however, be other uses for which it is conceivable that they may have been formed. The matter which composes their tails must fall in process of time to the sun or the nearest planet that may pass through it, where it may supply defects and answer purposes which our total ignorance of its properties scarcely allows us even to conjecture. In the sun it may serve to recruit the waste of matter that luminary may suffer by the constant emission of particles of light.

Perhaps the only distinction to be drawn between eighteenth and twentieth century ideas regarding the decay of the sun's mass is that the eighteenth century idea was thoroughly materialistic, while that of the twentieth century is just the opposite.

It is at once evident that the eighteenth century idea in this matter is properly to be described as Newtonian, for that great philosopher was one of the principal supporters of the corpuscular theory of light; but in what way are we justified in saying that the modern doctrine of the equivalence of matter and energy can be traced back to Newton and to Maxwell?

The principle of the inertia of energy was first announced by Einstein in 1905[2] as a consequence of the special theory of rela-

[2] *Annalen der Physik*, Vol. 18, p. 639, 1905.

tivity. Very soon after[8] he showed that this principle could be deduced from a strictly classical basis. Consider a hollow cylinder with closed ends, containing a movable plug or piston. Suppose at first that this piston is in contact with the left end of the cylinder with a trace of some explosive between them. If this explosive be set off the piston will be driven to the right and the cylinder, by the reaction, to the left. This relative motion will continue until the piston strikes the right end of the cylinder.

To an outside observer, unaware of the presence of the piston within, it would appear that the cylinder, without the application of any outside force, shifted its center of mass (or inertia) slightly to the left, in defiance of classical mechanics. If he was convinced of the correctness of the usually received mechanical principles, he might be led to infer that a concealed mass on the inside of the cylinder had shifted its center of inertia to the right to an extent sufficient to equalize the motion of the cylinder, and the hidden mechanism of the trick would stand revealed to the eye of reason.

Einstein considers a similar cylinder without any piston, but with the left end a little warmer than the right. If a pulse of radiant energy leaves the left end and travels through the cylinder to the right end we have a state of affairs analogous to that of the moving piston. As shown by Maxwell, on strictly classical grounds, radiant energy possesses momentum and will exert a pressure upon a surface against which it strikes; and by Newton's third law of motion, it must exert an equal and opposite pressure upon the surface which it leaves. The effect of this moving piston of radiant energy will be therefore to shift the center of mass (inertia) of the cylinder to the left by an amount too small indeed to be experimentally verified, but which an acceptance of classical theory requires us to recognize. By the cooling of the left end of the cylinder and the warming of the right end a certain amount of energy has been transferred from one end to the other; and to preserve the classical doctrine of the unchangeable center of inertia of a conservative system we must assume the simultaneous transfer of a small inertia from one end to the other. Maxwell showed that radiant energy possessed momentum; to this Einstein added the possession of inertia. In order to preserve unchanged the laws of classical mechanics the inertia equivalent of the energy-piston must be 9×10^{20} ergs per gram. This coefficient is the square of the speed of travel of radiant energy and gets into the formula because the speed of travel of the energy-piston is a factor in determining the shift of the cylinder. Were this speed infinite the cylinder

[8] *Annalen der Physik*, Vol. 20, p. 627, 1906.

would not have time to move at all before the impact on its far end stopped its motion; and the more slowly the energy travels the greater its inertia equivalent. The parallel to the material piston holds throughout.

Mass may be measured either by its inertia or its weight; in fact, inertia and weight (or gravitation) have always been regarded as the only two properties of matter sufficiently characteristic to serve as a basis for its definition: matter is that which possesses inertia and exhibits gravitation. It was the failure to show any ability to gravitate which brought the abandonment of Kelvin's ether-vortex atoms; inertia they had in plenty. Does energy possess weight as well as inertia?

We have seen that in the case of radioactive bodies there is a loss of energy which, in several thousand years, should cause a measurable change in inertia. There is no doubt that radioactive products of the necessary age lie ready to hand in the form of uranium and lead, the beginning and end of a chain of transformations which has required many thousand years for completion. So slowly does uranium break down that a portion of it may travel the long way to lead, while another portion still remains as uranium. If during these transformations the escaping energy carried off inertia without weight we might expect that uranium and lead would have equal weights but different inertias, and in consequence would not exhibit the same acceleration under the action of gravity. But this question of the proportionality of weight and inertia, or the variability of gravitation with the nature of the substance, has been subjected to very searching experimental tests, the most delicate of which are those carried out by Eötvös with his torsion balance.[4]

For most substances this investigator found that inertia and weight were proportional to an accuracy of one part in 200 million; for radium compounds, where only comparatively small quantities were available, the precision reached was about two parts in a million.

We may therefore safely conclude that energy possesses both of the characteristic attributes of matter, and that matter may be converted into energy with a definite numerical equivalent relation.

It is a poor rule that does not work both ways. If the union of oxygen and hydrogen to form water results in a slight diminution in the mass of the reacting substances, how will it be in the case of electrolysis of water? Will the resulting oxy-hydrogen gas weigh a trifle more than the water?

[4] *Annalen der Physik*, Vol. 68, pp. 11–66, 1922.

Yes, we must admit this to be the case, though the magnitude of the change is too small for us to pick up experimentally. The increase in mass must measure the energy applied to dissociate the compound. This leads us to view in a new light our concept of potential energy, which ceases to be an imponderable, and becomes a definite weighable quantity.

The idea of matter turning into energy is of such a transcendental character as to cause dismay and confusion to those of us who learned our elementary physics before the discovery of X-rays. Can we form any mental picture which will be helpful?

I think that this is possible. Einstein's theory of gravitation supplies us with a mental picture of matter which lends itself excellently to illustrating the conversion of matter into energy.

Einstein's theory of gravitation stands apart from all other attempts to explain this mystifying phenomenon in that he begins by denying that there is any force of attraction between two gravitating bodies. His strategy is excellent; having denied the existence of such a force he does not have to set up machinery to account for it. He replaces action at a distance by action in contact, of a transcendental nature, perhaps, but one of which a fair analogy can be given. It is like the deflection of a moving object by a surface of constraint.

Imagine a level surface of still water of indefinite extent; this surface will be two-dimensional, having length and breadth, but no thickness. The surface being perfectly flat, the geometry of figures traced upon it will be Euclidean, that is to say, the sum of the angles of a triangle will be exactly 180°, and through a given point only one parallel can be drawn to a given straight line. But suppose the surface, instead of being flat, is spherical, like the surface of the ocean viewed on the large scale; the geometry of figures traced on such a surface will then differ importantly from that of figures on a flat surface. On a spherical surface we can not, of course, draw a straight line in the usual meaning of that term; but we can draw one after Euclid's definition: the shortest distance between two points; and, as every navigator knows, this will be an arc of a great circle. There is a name used in general for such a shortest line traced on a curved surface of any kind: it is called a geodesic line. Its actual shape will, of course, depend on the way the surface is curved and the direction in which the line is drawn. On a cylinder, for instance, a geodesic may be a straight line, an arc of a circle or some intermediate form, according as it is drawn parallel, perpendicular or oblique to the axis of the cylinder.

On our spherical surface the three angles of a triangle (con-

structed of geodesics) will exceed 180° by an amount proportional to the area of the triangle. And upon such a surface two arcs of great circles will always intersect each other if sufficiently produced; that is to say, through a given point no geodesic (or "straight") line can be drawn parallel to (that is, not meeting) a given geodesic. A surface possessing these geometrical properties is called a surface of positive curvature.

On such a water-surface a floating particle, if set in motion, and free from the action of all forces, frictional, attractional or otherwise, would travel by the shortest, "straightest" path it could find, obeying Newton's first law of motion with the added condition of being confined to the spherical surface; that is to say, on a curved surface, the natural path of a body moving under the action of no force is a geodesic.

Surfaces of negative curvature may be constructed, on which the geometry is just the opposite of that on a surface of positive curvature; for on such a negatively curved surface the three angles of a triangle sum up to less than 180°, and through a given point more than one geodesic can be drawn parallel to (*i.e.*, never meeting) a given geodesic. Examples of such surfaces are the stem of a wine glass, a saddle or a mountain pass. On such a surface the geodesic, from a Euclidean point of view, would be a curiously twisted line.

Returning now to our flat surface of water, let us render it non-Euclidean by curving it in still another fashion. By careful manipulation it is possible to lay upon the surface of the water a particle of a heavy body such as lead, or even gold, so that it will float. The only thing necessary is to avoid breaking through the surface. The particle then lies supported by the unbroken water surface bent into a cusp or depression. Here we have a surface, normally two dimensional, bent or depressed slightly in the direction of a third dimension in the vicinity of a particle of matter. If we examine the geometry of figures traced upon the curved portion of the water surface, we shall find it non-Euclidean, and of negative curvature. The geodesic of this part of the surface will be a curved line of some kind; but if continued well beyond the cusp in either direction the geodesic will soon be indistinguishable from an ordinary straight line, and the geometry of these distant portions of the surface will be Euclidean.

Suppose now a comparatively heavy particle thus floating and forming a rather deep and widely extended cusp. At a great distance, in a Euclidean region of the surface, suppose a much smaller and lighter particle, which hardly produces any cusp, moving freely

along the surface in a direction that will carry it past the heavy particle at a short distance, well within the latter's cusp. The path of the moving particle, at first a straight line, will as it enters the cusp gradually assume the curved or geodesic form proper to the space in which it finds itself. Assuming no attractive force to exist between the particles, the moving particle will pass on and out of the cusp, its path again becoming straight; but on account of the brief twist to which it was subjected in passing through the cusp the final straight portion of the path will not in general be a continuation of the first straight portion. The particle will have suffered a permanent deflection.

An observer watching the motion of the particle through what we may call Euclidean-Newtonian spectacles, which do not show him the curvature of the water surface, will say: "Yes, on passing the heavy particle the light particle seems to have suffered a force of attraction of some kind, and to have been deflected from its straight path." But let him replace these glasses by others of Einsteinian make, and he will say: "No, I see now that there was no force of attraction at all. It was purely the inertia of the moving particle combined with the peculiar curvature of the surface which it had to traverse that produced the change in its path."

In the later development of Einstein's theory there is to be found a tendency to say not that a particle of matter has a space-cusp surrounding it, but that the cusp itself constitutes what we call a material particle. On this view the equivalence of matter and energy follows easily. Matter is static, an initial distortion in "space"; energy is kinetic, the spreading ripple into which the initial distortion is converted when whatever is holding it lets go. On this view there is little to choose between the old concept of an ether and Einstein's concept of space. If space can be bent it may be straightened, and if this process be repeated frequently enough the space may be said to vibrate. Endow Einstein's "space" with resiliency as well as deformability, and we have something which strangely resembles the old-fashioned "ether."

But what happens when energy is reconverted into matter, as we have seen must take place in the electrolysis of water, or in any process which involves an increase in the potential energy of the system? It is not inconceivable that if the amplitude of the energy waves reaches a certain intensity the medium which carries them, call it space, ether or what you will, may acquire a permanent or quasi-permanent distortion, like a body which has been strained beyond its elastic limit. Such a distortion may slowly straighten out again under the stimulus of passing waves, perhaps by discrete

jumps, as the quantum theory demands, much as a pile of cannon balls may be conceived to disintegrate under the influence of a mild and continuous earthquake, one ball at a time being dislodged and rolling down. In particular, such an intensity might conceivably be reached if our space has a slight positive curvature, analogous to that of a sphere; for then radiation starting from any point must eventually converge to the opposite "pole" of the universe, where its intensity must be as great as at the starting point. It is a curious idea, this of matter distilling, so to speak, from one pole and condensing at the other, through the intermediate phase of radiant energy. It possesses at least this recommendation, that it holds out a way of escape from the intellectually intolerable position of having to suppose that the ultimate fate of radiant energy is to travel, like the Wandering Jew, onward for ever.

"Upon this supposition of a positive curvature," said Clifford, fifty years ago,[5] "the whole of geometry is far more complete and interesting. . . . In fact, I do not mind confessing that I personally have often found relief from the dreary infinitudes of homaloidal space in the consoling hope that after all this other may be the true state of affairs."

[5] "The Postulates of the Science of Space"; Lectures and Essays.

OUR IMMIGRATION POLICY AND THE NATION'S MENTAL HEALTH

By Dr. WALTER L. TREADWAY
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Since the development of the first settlements in the North American continent efforts have been made to prevent the introduction of undesirable elements into the population. Attempts were made by the colonies, the several states, and finally our national government undertook to skim the dross from that ever-increasing mass of humanity which sought admission to the new world. A distinction is made, however, between those who took part in building the political framework of the thirteen colonies and the Federal Union and those who arrived to find the United States Government and its social and political institutions in working operation. The former have been called "colonists" and the latter "immigrants."

The menace of the dependent and defective classes who arrived in this country during the colonial period influenced the colonies to enact laws for the support of their poor and impotent and to impose penalties upon masters of vessels for bringing undesirable persons into their provinces. Irrespective of the liberal welcome accorded new settlers during that period, colonial laws all bear witness to a unity of opinion concerning the exclusion of dependent and defective classes. Even at that early date it had become imperative to adopt a policy of imposing penalties upon common carriers for bringing in undesirable settlers. This policy was later adopted by the legislatures of the several states and finally by the national government itself.

After 1838, however, the necessity for excluding undesirable immigrants became more pressing. It was then that a great turning point occurred in the influx of immigration to this country. In that year the *Great Western* sailed under steam from Bristol to New York, and two years later Samuel Cunard crossed in his first steamship, the *Britannia,* from Liverpool in fourteen days. The advent of transatlantic steamships lessened the terrors of an ocean voyage and reduced the cost of an emigrant's passage from pounds to shillings.

Until 1882 the majority of immigrants came from northern and western Europe. This movement of peoples has been called the "old immigration." For many years they were predominately

Irish, the English, Welsh and Scotch following closely in aggregate numbers. Immigration from the British Isles continued the dominant group until 1854, when their numbers were exceeded by emigration from Germany. The immigration occurring since 1882, however, has been associated with an increasing number of persons from southern and eastern Europe. This movement of peoples is sometimes termed the "new immigration."

The separateness of life and habits of newly arrived immigrants has usually invited antipathy from the natives, who tend to develop a feeling of contempt toward all immigrants of the poorer class, irrespective of their race. To the mind of the average native American, the typical immigrant has been and is regarded as a being uncleanly in habits, uncouth in speech, lax in morals, ignorant in mind and unskilled in labor. The immigrant has often borne a stamp of social inequality, suggesting an impersonal antipathy on the part of the native-born.

This sentiment, which existed toward the old immigration as well as toward the new, eventually crystallized the essential features of "nativism," which first gave rise to the so-called "Nativist" and "Know Nothing" movements. Through the efforts of those supporting the nativist movement memorials were sent to Congress urging a repeal or modification of the naturalization laws and the passage of laws to prevent the introduction of undesirables from foreign countries. This led to the appointment of a special congressional committee to consider these questions.

This committee ascertained that Great Britain was legalizing the deportation of its paupers; that many immigrants were admitted to almshouses within a very short time after landing, in some instances within a few hours; that persons convicted of crimes in Europe were promised amnesty upon emigrating to the United States; and that criminals condemned to life imprisonment were taken directly from the prisons of Germany and deported to America. As a result of these findings the committee presented a bill to Congress on February 19, 1838. It proposed a fine of $1,000 or imprisonment from one to three years for any master who took on board his vessel with the intention of transporting to the United States any alien passenger who was an idiot, a lunatic, afflicted with any incurable disease or convicted of any infamous crime. It further provided that the master of the vessel should forfeit $1,000 for any alien brought to the United States who had not the ability to maintain himself. This bill was never considered. It is noted, however, that the memorials to Congress largely responsible for the appointment of this committee urged the adoption of a system of consular inspection of immigrants before embarkation.

It was during the late 40's and early 50's, when transatlantic steamships were bringing immigrants in ever-increasing numbers, that the sentiment against foreigners was revived and the so-called "Know-Nothing" movement became most active. Its supporters advocated laws restricting the immigration of the dependent, defective and criminal classes, but by 1858 this movement had disappeared, to be replaced in the early 60's by sentiment advocating unrestricted immigration.

In 1864 Congress authorized the importation of "contract labor"; the appointment of a commissioner of immigration to arrange for the transportation and care of immigrants until they reached their final destination; and preparations were made for the appointment of special agents in European countries to promote and assist immigration. This sentiment subsided with increasing immigration, however, and in 1868 the Act of 1864 was repealed. With its repeal public sentiment became more and more crystallized in its demands for regulating immigration.

The regulation of foreign immigration, which had been entirely under the jurisdiction of the separate states, was fast growing beyond their control and frequent requests were made for national aid of some sort. The public's demand for this aid was partly justified by an investigation conducted by the Department of State in 1874, when it was definitely proved that foreign officials of many European nations were deporting to the United States convicts, paupers, idiots, insane and others incapable of self-support. Congress protested these acts, and restrictive legislation was proposed but not enacted. Federal aid eventually came, however, for in 1876, by a decision of the Supreme Court, all state laws relating to immigration were declared unconstitutional and the authority for its regulation declared vested in the national government alone.

It was not until 1882, six years after state regulations were declared unconstitutional, that the first federal immigration law was enacted. It provided for the exclusion of foreign convicts, lunatics, idiots and persons likely to become public charges. Several defects existed in the first federal immigration law, however. No penalties were imposed for the illegal landing of excludable aliens, and no provisions were made for the temporary care of immigrants. Local agents who conducted inspections and examinations were appointed by their respective states, but were neither paid by the states nor by the federal government.

These defects were not corrected until 1891, when a new law was enacted. It debarred idiots, insane persons, those insane within three years after admission, those having had two or more attacks of insanity, those suffering from loathsome or dangerous contagious

diseases, polygamists, felons and those who had been convicted of crimes involving moral turpitude. Penalties were imposed upon persons bringing aliens not lawfully entitled to enter, and medical examinations at ports of arrival were henceforth to be conducted by officers of the United States Public Health and Marine Hospital Service. A notable feature of this law was that transportation companies were required to return all persons coming unlawfully and, in addition, to return those who became public charges within one year after landing. It also prohibited common carriers from soliciting emigration except by ordinary advertisements.

This law was further elaborated in 1893 when masters of vessels carrying immigrants were required to give more detailed reports of each passenger. In 1894 the President was authorized to appoint immigration commissioners at the several ports for a term of four years, and in 1895 to appoint a commissioner general of immigration. It was also about this time that a proposed system of consular inspection of immigrants was revived. A bill proposing such a system was introduced in the second session of the fifty-third congress, but being opposed by the state and treasury departments, it failed to pass.

In 1896 a literacy test was recommended as a means of excluding that class of immigrant which investigation had shown contributed most heavily to pauperism, crime and juvenile delinquency. This feature in the regulation of foreign immigration was not enacted into law until some years later, however. In 1903 Congress saw fit to modify the immigration laws. During that year it increased the period of possible deportation of those insane within five years after landing and added professional beggars and anarchists to those already excludable.

No further changes were made in the immigration laws until 1907, when stricter measures were taken to prevent the importation of undesirables. Even this law was not adequate, for the problem of immigration was becoming more and more a problem of national importance. In 1911 the United States Immigration Commission was appointed. It made an intensive study of immigration and published a voluminous and illuminating report. In February, 1917, largely resulting from the work of this commission, the Act of 1907 was broadened in scope. It made more far-reaching provisions for the deportation of those having been sentenced to terms of imprisonment for crimes involving moral turpitude, and those becoming public charges within five years after landing. It excluded the insane; idiots; imbeciles; feebleminded; chronic alcoholics; constitutional psychopathic inferiors; the mentally defective whose defect would modify their ability to earn a living; those

with loathsome or dangerous contagious diseases, and those over sixteen years of age who were without a reading knowledge of some language. Thus, the literacy test, first proposed in 1896, eventually became a law.

From a review of the immigration laws considered thus far, it is evident that a unity of opinion has existed for skimming the dross from the peoples of Europe who seek admission to our country. All legislation seems to have been fostered by demands for the exclusion of the mentally and socially unfit. Regardless of the improvement in legislation, however, mentally disordered persons continue to seek admission. Earnest attempts have been made to exclude these undesirable aliens in two ways; by examinations at the port of arrival, and by imposing penalties upon common carriers for bringing them. Partial success has been achieved by these measures, but no machinery has been developed that will exclude those potential misfits or doubtful cases who possess latent qualities for injury to the community or national welfare.

A measure of the success attendant upon the examinations at ports of entry may be obtained by an analysis of the certificates issued for mental disorders by those concerned with examinations at the ports of arrival. During the 22-year period from 1900 to 1921, 17,957,807 arriving aliens were inspected and examined by officers of the United States Public Health Service. Of this number 6,629, or 36.9 per each 100,000, were found to be afflicted with mental disorders of one kind or another. These do not embrace the doubtful cases, but only those who are mandatorily excludable under the law.

The rate of debarment for some of the principal racial groups is illustrated in Fig.1, which indicates that the northern and western European generally contributes a higher proportion of mental disorders detected at ports of entry. The Mexican and Irish races suffer most from the hardships and inconveniences of deportations because of mental disease.

In addition to the restrictive measures embodied in the examination of aliens at ports of entry, the immigration laws have imposed certain penalties upon common carriers for transporting any of the excludable groups. A fine of $200 was imposed by the law of 1917 for transporting a mandatorily excludable alien whose disability could have been detected by means of a competent medical examination abroad. In addition, a sum equal to that paid by the alien for his passage from the initial point of departure was collected and returned to the immigrant. A penalty of $25 was also imposed for bringing any person with a mental or physical defect which might affect his ability to earn a living, provided that such defect

could have been detected by competent medical examination before embarkation. The master, or first officer of the vessel, was required to verify the ship's manifest or passenger list by oath and signature. This oath attested that the ship's surgeon had been required to make a physical and mental examination of each alien passenger and that no alien embarked who was excludable under the law.

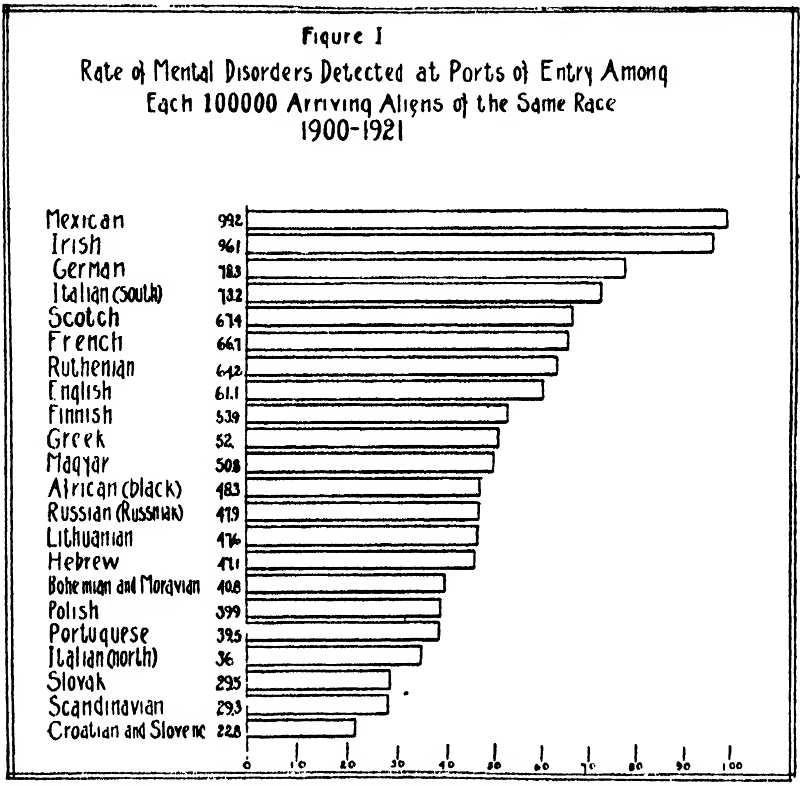

FIG. 1

The value of the examinations of aliens at ports of entry and the imposition of penalties upon common carriers for transporting mandatorily excludable aliens may have influenced the number of foreign-born admissions to public hospitals for the insane who had resided in this country for varying periods of time. For example, in New York state, among all foreign-born admissions to institutions for the insane in 1909, 22 per cent. had been in the country less than five years; 13 per cent. for five years but less than ten; 20 per cent. for ten years but less than twenty; and 43 per cent. for twenty or more years.

In 1920, however, this situation had changed. In that year only 4.7 per cent. of the foreign-born admissions had been residents of

this country for less than five years; 17 per cent. for five but less than ten years; 29 per cent. for ten but less than twenty years; and 35 per cent. for twenty or more years. But these changes are greatly influenced by differences in the length of residence of the foreign-born population for the two periods. Thus, in 1910, 25.3 per cent. of the foreign-born population of the United States had been residents for less than five years, and only 14.3 per cent. of the admissions to all institutions for the insane in the United States had been residents less than five years. In 1920, only 5.7 per cent. of the foreign-born population of New York state and 4.7 per cent. of the insane first admissions to New York state hospitals had been residents less than five years. Those within the second five-year period of residence, however, contribute a proportionately higher number of insane. Among those who had been residents of the United States for ten or more years, the number of insane recruited therefrom was proportionately greater in 1910 and proportionately lower in 1920. How great a factor the regulation of foreign immigration was in influencing this situation can not be accurately determined from data at hand.

Since the foreign-born population contributes a relatively high proportion of insane among first admissions to institutions, it is likely that among all arrivals an unknown proportion possess potentialities for the development of mental disease. Congress evidently recognized the necessity for excluding those who were potential misfits and also the doubtful cases who possessed latent qualities for injury to the community or national welfare. Thus, the new immigration law, which became effective on July 1, 1924, imposed greater penalties upon transportation companies for bringing excludable aliens to this country. The new law provided a penalty of $1,000 upon common carriers for bringing an alien with an excludable disease that could have been detected by competent medical examination at the time of embarkation. This penalty included a sum equal to that paid by the alien for his transportation, the latter sum being returned to the immigrant. The rigid enforcement of this feature of the new law will probably act as a deterrent to steamship companies accepting as passengers those in whom a reasonable doubt exists regarding their physical or mental health. The excludable groups comprise "any alien afflicted with idiocy, insanity, imbecility, feeblemindedness, epilepsy, constitutional psychopathic inferiority, chronic alcoholism, tuberculosis in any form or a loathsome or dangerous contagious disease.

But the new immigration law also provides for a system of consular visas of immigrants' passports and issues such visas in keeping with the quota of each nationality. The issuing of a consular indorsement does not permit an alien entry to the United States if he is otherwise an inadmissible person. These visas are of two kinds: those for "quota immigrants" and those for "non-quota immigrants," the act specifically defining both classes. A system of consular inspection abroad, first advocated in 1838, may prove to be of great value in excluding potential misfits from our shores. However, the withholding of a consular indorsement, particularly for those with frank mental and physical disorders, is certainly a humane procedure and will tend to lessen those hardships and disappointments incident to future deportation proceedings.

Any scheme for the better selection of immigrants, however, must consider that probationary period through which an alien passes before becoming a citizen of the United States. At present, if he becomes a public charge within five years after arrival he is subject to deportation. Other social tests besides that of becoming a public charge may be used to determine his desirability for citizenship. Such tests may be utilized eventually to determine whether an alien may or may not continue his residence in this country.

THE ATTACK ON THE GENE

By Professor JAMES W. MAVOR

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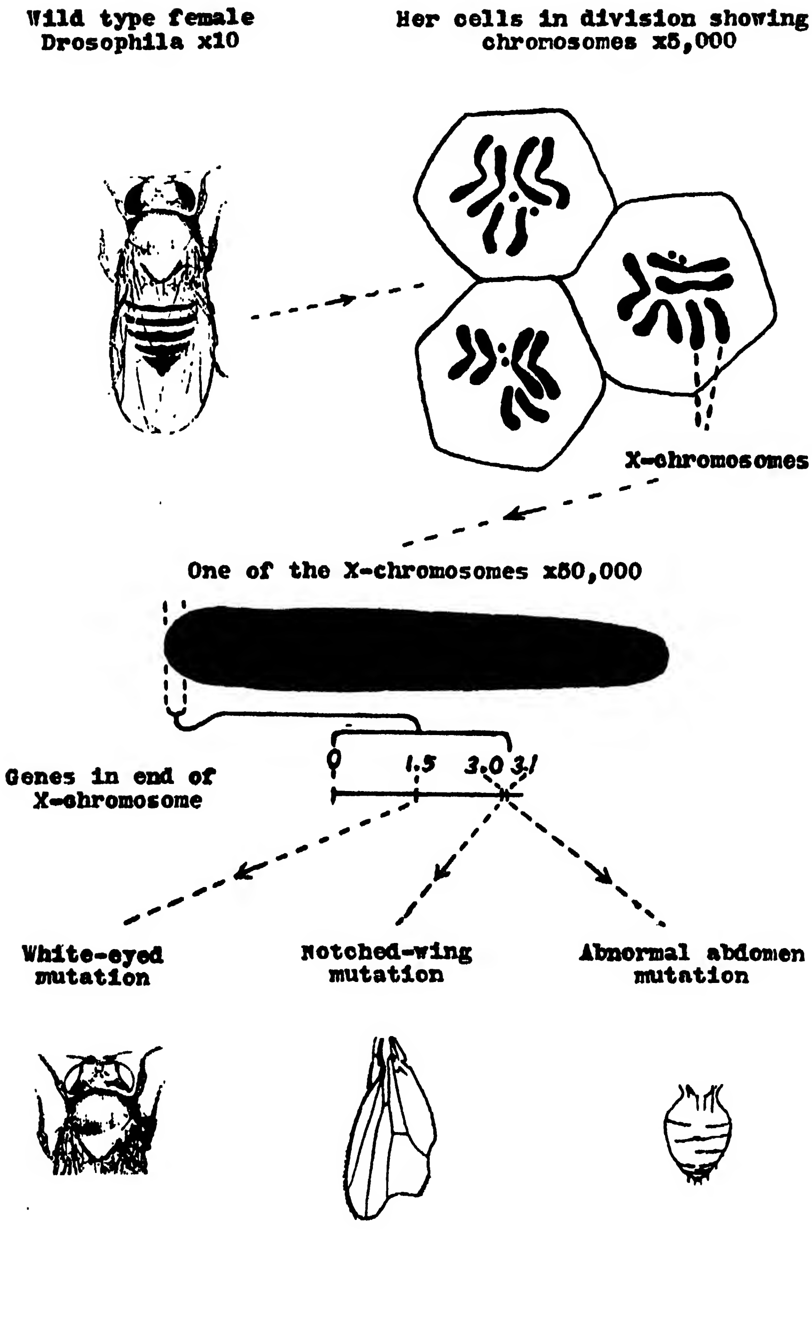
At the present time biologists are intensely interested in little things which they call genes. The conception and demonstration of the gene has crystallized many vague ideas and put the whole subject of heredity on a concrete basis. The genes have therefore in the minds of the students of this subject come to assume a most important rôle. They are the ultimate elements, the carriers of the unit characters. Upon the possibility of their alteration by experimental means rests the real answer to the question whether man can or may expect to modify heredity. And since the issue has become so clearly defined there is a feeling among those who are working in this field that at any moment very important discoveries may be made.

During the last twenty years the intensive study of inheritance has drawn more and more attention from professional biologists. Their combined efforts have now provided us with a fairly clear and detailed picture of the mechanism by which at least a considerable proportion of the hereditary characters are transmitted. Most is known about those characters which have been called unit characters, since they behave in a way as units, being passed from generation to generation without visible alteration and in such a way that an animal or plant either has or has not the character. Corresponding to these unit characters are certain minute bodies located in the germ cells, and indeed in every cell of the body, which are responsible for the transmission of the characters from one generation to the next. These are the genes. So far it has not been possible to demonstrate the genes microscopically, but they are known to be aggregated in certain clearly defined bodies called chromosomes. Chromosomes have been studied under the microscope not only in dead cells where minute details can be seen but also in living cells where their movements in cell division can be followed. It has further been possible to demonstrate by statistical methods that the genes are arranged in the chromosomes in a certain definite order.[1] So there is now no doubt in the minds of those

[1] Regarding figure 1, it is to be noted that, notched wing being dominant, the gene for it could not be present in the chromosomes of a female showing the characters of the wild type. White-eyed, being recessive, might however be carried by such a female. Abnormal abdomen although dominant depends for its appearance on certain environmental conditions. The outlines of the chromo-

Chromosomes and Genes in Drosophila



competent to judge that the hereditary characters are real things and that they are controlled by genes located in the chromosomes. This detailed knowledge of the mechanism of inheritance is by no means confined to the lower animals and plants. Many human characters are known, and the number is being constantly added to, which are transmitted according to the well-known laws of heredity. Microscopic study of the chromosomes of the human germ cells has shown that they agree in structure and mode of distribution with what has been generally demonstrated for animals.

There are few fields into which the methods of science have penetrated which have a more direct bearing on man's destiny than that which has to do with the handing on and possible modification of the great heritage which he carries in his own body and bequeaths to his children. The attempts to modify heredity have necessarily been made on the lower animals, but there is no doubt that the general conclusions to which they lead apply equally to man. It may be remarked incidentally that in none of the experiments discussed in this article have the animals been given any painful treatment.

We are all more or less familiar with the method of experimental breeding. When animals or plants with a number of unlike hereditary characters are bred together their offspring usually possess a mixture of the characters of their parents, but the individual characters as, for example, color and structural peculiarities, when expressed retain their individuality and are passed unaltered through successive generations. Such a method does not in itself introduce anything essentially new. It produces only a different combination of characters which were already present in the parents. A second method which has been tried is to produce some modification in one or both parents in the hope that this same modification may be detected in the offspring. In some cases the parent is injured, as in Weismann's famous experiment with mice from which the tails were cut. In other cases the modification takes the form of an apparent adaptation to a new environment, as in Dr. Kammerer's experiments with salamanders. With regard to experiments of this kind it is safe to say that those who have gone into the matter agree that there is no well-substantiated case of an experimentally produced modification of a parent being transmitted to its offspring.

In all the cases in which it is admitted that a modification of heredity has been produced it is the germ cells which have been

somes are from Bridges, *Genetics*, Vol. 1, the wild fly from Morgan, "The Physical Basis of Heredity," the notched wing from Dexter, *American Naturalist*, Vol. 48, and the abnormal abdomen from Morgan and Bridges, Carnegie Institute publication, no. 237.

themselves directly modified. The external agent or some factor in the environment has acted directly on the germ. It is true that in some cases the body of the parent may also have been affected, but the modifications of the germ cells and the parent body are collateral, so that there is no question of an adult animal being modified in such a way as to transmit the modification to its offspring. The distinction made here may seem to be somewhat academic. It is none the less fundamental and essential to a clear understanding of the problem. A good case in point is that provided by Dr. Stockard's experiments. Guinea pigs were intoxicated with the vapor of alcohol on successive days over a considerable period of time. The offspring of animals treated in this way showed various abnormalities, chiefly of the nervous system and eyes. The animals with these abnormalities did not breed. However, apparently normal offspring from the treated animals had abnormal young. Dr. Stockard's explanation is that the reproductive organs and germ cells became injured. It is known that alcohol can penetrate through the tissues of the body and reach the germ cells. Dr. Guyer's experiments on rabbits, although very different from those of Dr. Stockard, are nevertheless probably to be explained also as a case of a direct effect on the germ cells. Pregnant rabbits were injected with a serum made antagonistic to the development of the lens of the eye. Certain of the young from such rabbits showed defects which they transmitted to their offspring.

In experiments of the kind described it has not been possible, up to the present, to analyze the results in such a way as to determine what part of the hereditary mechanism has been affected or to determine whether one or more genes have really been modified. It is quite possible that in these experiments there may have occurred only a loss or an abnormal distribution of chromosomes as in experiments to be considered later in this article. It may, however, be remarked that Dr. Little has studied the inheritance of certain defects which occurred in the offspring of mice exposed to X-rays, but he does not claim to have proved that the abnormalities were due in the first instance to X-rays or any external agent. This method, then, of attacking the problem, *viz.*, by treating normal parents or their germ cells with modifying agents such as alcohol, serum and X-rays, has so far not yielded any information as to the way in which the external agent modified the germ cell.

Mention has already been made of the mechanism of heredity—of how each unit character, as, for example, a particular color of the eye or body, is carried over from parent to offspring in a gene. The genes have been located in the chromosomes and each germ cell, be it an egg cell or a sperm cell, carries a full complement of the

chromosomes characteristic of the species. In the case of the common fruit fly (*Drosophila melanogaster*) somewhat over three hundred different unit characters have been investigated and the genes corresponding to them located in one or other of the four different chromosomes found in the mature eggs and sperm. The sperm cell when it fertilizes the egg brings with it its contribution of four similar chromosomes so that the fertilized egg and all the millions of body cells into which it divides to form a new individual each contains eight chromosomes, forming, however, four pairs, one of each pair having come from the mother and one from the father. By this microscopic mechanism the offspring inherits in a general way equally from its two parents. This statement must be qualified. While the genes occur in pairs, one coming from the mother and the other from the father, they may not be exactly the same so that while the maternal chromosome may carry in it a gene which causes the offspring to have red eyes the corresponding chromosome derived from the father may carry in place of a gene causing the formation of red eyes one which would cause the eyes of the offspring to be white. In such a case the eyes of the offspring are red in spite of the fact that only one of the pair of chromosomes carries the gene for red eyes. In this case the character and the gene are said to be dominant. If however such a hybrid individual is bred the white eye or recessive character will come out in its offspring. An animal or plant will continue to breed true only when the genes in both its chromosomes are alike.

There is a further complication involved in the transmission of certain of the hereditary characters and in the determination of sex. We referred to the fact that each mature germ cell of the fruit fly contains four chromosomes and each fertilized egg cell and each of the cells of the individual to which it gives rise contains four pairs of chromosomes. When now the germ cells are matured in the body of this individual each has again only four chromosomes, the members of each pair of chromosomes having been separated in the process of maturation. In the cells of the body of the female the two chromosomes of each pair are exactly alike, although they may not contain identical genes. In the cells of the body of the male on the other hand the two chromosomes of one of the pairs are not alike, one of them being identical with each of those in the corresponding pair in the female. This chromosome has been named the X chromosome and it is usual to speak of the cells of the female as containing two X chromosomes and those of the male as containing one X chromosome and one Y chromosome. It therefore comes about that when egg cells are matured in the female they are all alike and each contains one X chromosome, while when

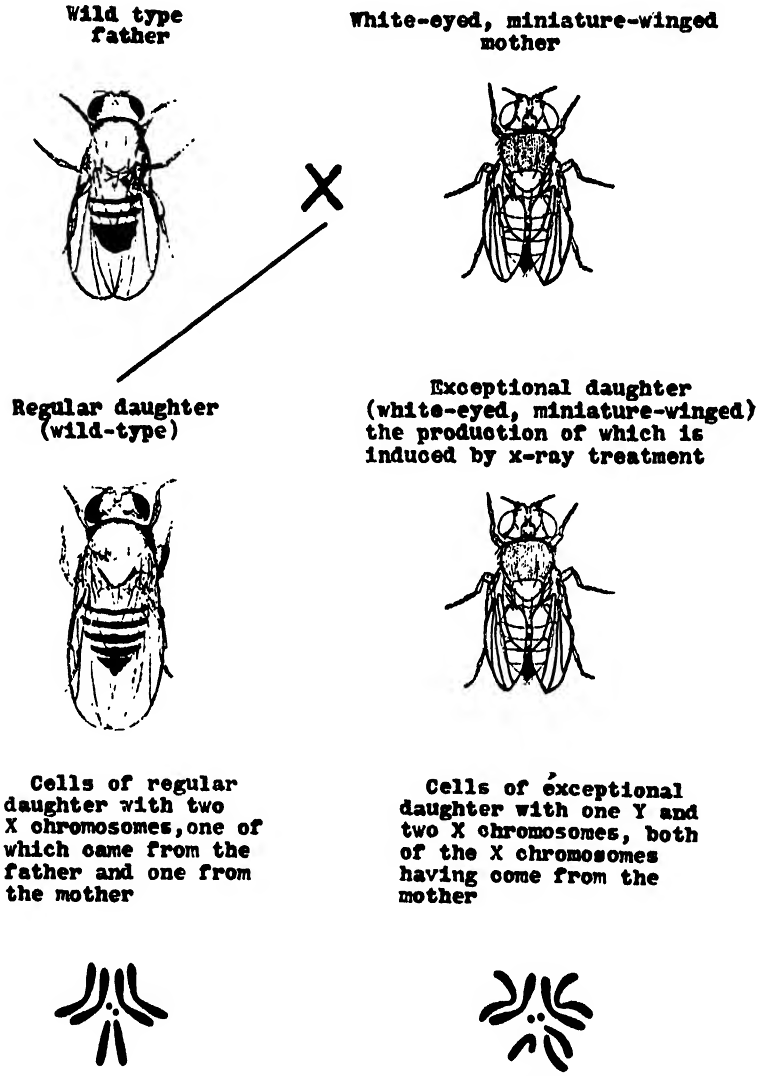
sperm cells are formed in the male they are of two kinds, one kind containing an X chromosome and the other kind containing a Y chromosome and that when an egg is fertilized by a sperm cell containing an X chromosome it comes to have two X chromosomes and to be a female, while an egg which is fertilized by a sperm cell containing a Y chromosome comes to have an X and a Y chromosome and develops into a male. It appears further that no genes are carried in the Y chromosome. Such is the mechanism by which unit characters are transmitted from parent to offspring in the fruit fly. While the number of pairs of chromosomes differs in different species the mechanism is believed to be fundamentally the same throughout the animal and vegetable kingdoms.

With every germ cell nature deals to the future individual a hand of cards. These cards are the genes, and as his body plays the game of life the cards come out and some, standing high, are dominant, as we say, and take the tricks, and some, standing low, are recessive, and show their value only in the presence of other low cards. For each new deal the cards are shuffled, but they are in almost every case the same old cards.

Thus is insured not only that the parents in general equally contribute to the heritage of their offspring but also that this heritage becomes equally distributed among all the cells of the offspring and all their germ cells. This aspect of the biology of the cell has been worked out with the most minute detail of recent years and its application to explain the immense accumulated knowledge of the external phenomena of heredity constitutes one of the great accomplishments of biology during this century. So extensive is now the data and so confident are those who work with it that it is possible to say that a given hereditary behavior, *i.e.*, certain results for certain crosses, implies the corresponding microscopic processes in the germ cells. To be more precise if a given male fruit fly has white eyes it is certain that in its cells there is but one X chromosome and that in this X chromosome lies the gene for white eye, and in a female fly with white eyes it is possible to be certain that in the cells of its body there are two X chromosomes and that each of these X chromosomes has the gene for white-eye color.

Now this little mechanism with its genes and chromosomes and the forces which keep them apart or bring them together is just the sort of thing with which the chemist and physicist delight to experiment. Processes which depend, like those which govern the distribution and segregation of the genes, on delicate adjustments of chemical and physical forces, yield readily to modification and control by modern technical methods. The difficulty of the problem lies not in finding methods calculated to modify and control

The Effect of X-Ray Treatment of the Eggs upon the Offspring of the Fruit Fly, Drosophila



the mechanism of inheritance, but to apply methods in such a way as not to destroy the life of the cell.

In the experiments to be described next a beginning has been made in this fascinating and romantic field. The physical agent applied to the cells was X-rays, long known to produce striking effects on the chromosomes. As is well known, X-rays have the peculiar property of penetrating to all parts of the animal. It is

therefore only necessary to expose the entire animal to the X-rays in order to treat the germ cells, and indeed the germ cells are so sensitive to X-rays that an exposure which causes marked changes and even death in the germ cells leaves the rest of the animal practically unaffected. Such experiments require, however, not only a critical application of physical forces but also the careful choice of an animal in which slight changes in the hereditary mechanism can be observed. Such an animal is the common fruit fly already referred to.

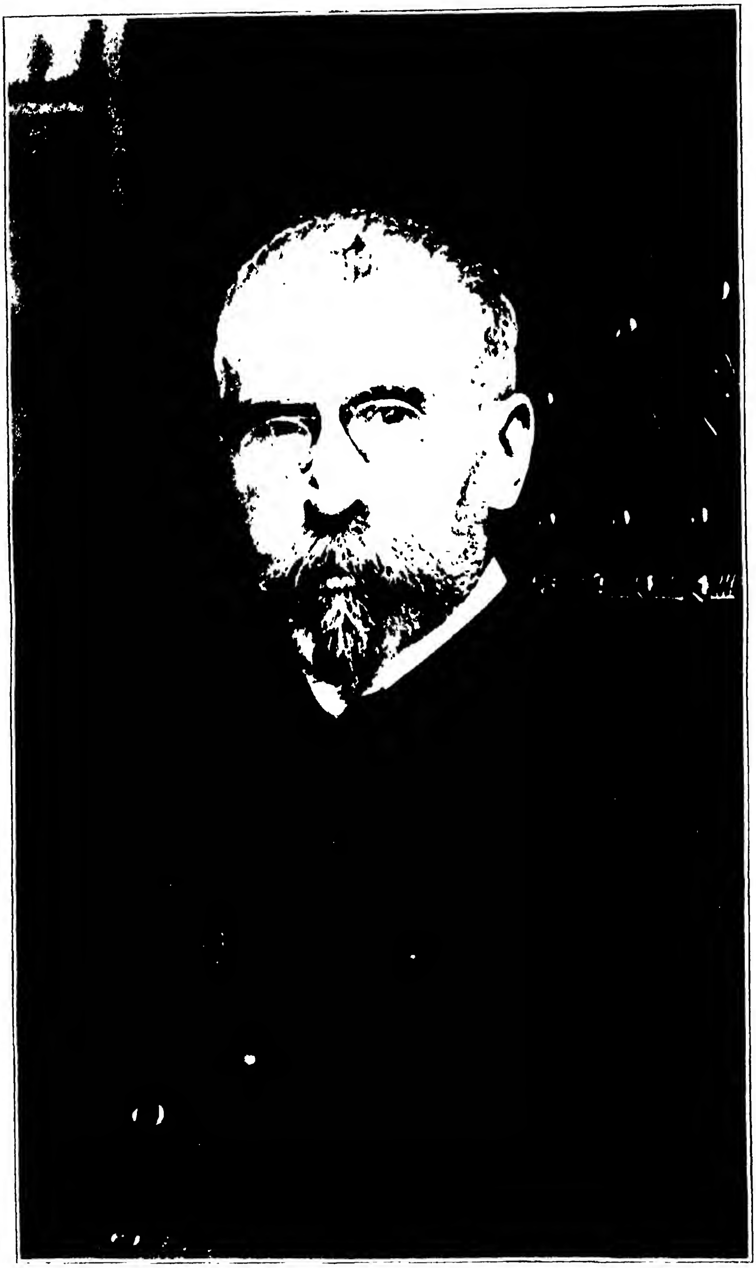
Considerations such as those outlined above led the writer to treat with X-rays fruit flies whose hereditary constitution, so far as certain well-known unit characters were concerned, was exactly known. The unit characters chosen were white-eyes as contrasted with normal red-eyes, and miniature wings as contrasted with normal wings of which they are about half the size. The genes for these characters are located in the X-chromosomes. Female flies were treated and in this way their eggs were exposed to X-rays before fertilization. When these were bred to normal males the exact effect on the offspring could be observed, from which it was further possible to determine the effect on the chromosomes and arrangement of the genes among the chromosomes. The experiments have shown that one effect of the X-rays is to cause the elimination of the X chromosome from the egg or to cause the formation of mature eggs with two instead of the usual one X chromosome. Such eggs give rise to flies peculiar in their hereditary characters and the way in which they breed but otherwise normal. Another effect of the X-rays is to alter the assortment of the unit characters among the different offspring—an effect that can be traced to a decrease in the frequency with which the chromosomes may break into pieces. However, in spite of these peculiar and rather profound effects on the mechanism of the inheritance of unit characters no conclusive evidence has been obtained that any individual gene or unit character has been altered, although during the course of the experiments somewhat over one hundred thousand flies developed from X-rayed eggs have been studied.

The conclusion to be drawn from all these investigations is that in no case has it been demonstrated that an individual gene has been modified by experimental means. It can equally be said, however, that there is no proof that the gene can not be so modified, and we know that genes do naturally change or as we say mutate.

Seldom do those who follow science turn back from the attack upon the problems to which the advance of knowledge leads. So the assault upon the gene will continue. What form will it take? At the present moment there are two promising lines of work. The

first is chemical and consists in searching for some substance which while penetrating through the cells of the body and into the germ cells reacts specifically with certain of the genes. The other method is physical and consists in attempting to find a physical condition such as a particular pressure or temperature which affects only certain genes or a kind of ray or other mode of energy which can be concentrated in the cell in a point of sufficient fineness to affect a single gene or a small group of genes. If any kind of radiation were used the point of the beam would have to be less than one millionth of an inch in diameter. It is essential that only a single or at most a few genes be affected, since we know that sorted in with the genes of the hereditary characters which we recognize as such are other genes, probably more numerous, whose disturbance leads to death. What a delicate adjustment is life and how refined must be any attempt to interfere with its fundamental processes!

There is a feeling prevalent not only among laymen but also among members of the medical profession that experiments on "the lower animals" throw little light on human problems. This feeling is undoubtedly changing and may soon be a thing of the past. Even now the up-to-date medical man looks at his subject from a "biological point of view" and our schools of social science give courses in "civic biology." One has only to pass over in his mind the discoveries which have most advanced our knowledge of "the nature of man" to realize how large is the proportion due to biologists in the larger sense of that word as used now. Nor has the immediate and direct application of their discoveries been less striking. Whether we will or not biology is moulding our lives.



DR. ÉMILE ROUX
Director of the Pasteur Institute in Paris for twenty years (1904–1925).

THE MEDICAL WORK OF PASTEUR[1]

By Dr. ÉMILE ROUX

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(Translated from the French by Erwin F. Smith, U. S. Department of Agriculture, Washington, D. C.)

THE medical work of Pasteur begins with the study of fermentations. From the beginning men have associated fermentations with infectious diseases and regarded viruses and ferments as of the same nature. But between fermentation and disease there is this difference, that the fermentable medium is inert, that we can compound it as we please with definitely weighed-out materials while the body of the infected animal is living and of a complexity hitherto impossible to penetrate. Consequently, the study of fermentation is easier than that of infectious disease and naturally precedes it.

[1] A generation has passed since this paper was written (1896) but it is still as interesting as ever. It is, in fact, the best brief paper we have on the work of Pasteur and the writer of this note believes many will like to have it in an English dress.—E. F. S.

The various doctrines on the origin of life have always run up against the doctrine of fermentations. No other question has more excited religious and philosophic passions than that of the ferments, which, we must acknowledge, do not diminish their obscurity. Pasteur understood that on such a subject he ought not to advance anything which did not rest upon clear proofs and from the beginning he restricted himself to a scientific method which resolved each difficulty by an experiment, simple to interpret, an experiment which charmed the mind and at the same time was so decisive that it satisfied him like a geometric demonstration and gave him a feeling of security.

It was, therefore, from 1857 to 1865 that the great struggles took place over fermentations for the principles out of which has come forth triumphant the doctrine of germs. Pasteur had already revolutionized medicine before having undertaken the study of a single disease. Each one of the fundamental principles established for fermentations applies with the same exactitude to infectious diseases; in fact:

The virus is a living being like the ferment. Both are microbes, as we would say to-day.

The virus by multiplying in the body causes the infectious disease, as the ferment multiplying in a fermentable medium causes the fermentation.

To each infectious disease there corresponds a specific virus, as to each fermentation a special ferment.

The virulent disease is not spontaneous, any more than the fermentation. The virus comes from outside, and consequently contagion can be avoided.

The extension to diseases of notions acquired in the study of fermentations brought about unheard-of progress. Surgery, whose interventions so often provoked redoubtable infections, became henceforth beneficent. Enlightened by the experiments of Pasteur, Lister comprehends that the complications of wounds are due to microbial germs coming from outside and he invents antiseptic dressings. With antisepsis begins the new time in surgery. Thanks to an experiment on fermentations, well done, Pasteur, who had never touched a scalpel in his life, nor made a surgical dressing, has saved more wounded than all the masters of surgery.

These labors of Pasteur upon the fermentations have given to medicine not only a doctrine, but also a method of research and a technique of marvelous power.

In order to study fermentation, Pasteur prepared first of all a *pure* fermentable substance, that is to say, one which did not contain any living thing. He obtained it in these conditions by steril-

izing it with heat. Thus heated, this nutrient medium preserves itself unchanged, indefinitely. Pasteur then sowed it with a trace of the ferment *in a state of purity*, that is to say, containing no other microscopic organism, which, developing along with it, might falsify the result of the experiment. This necessity for *pure cultures* imposed itself on Pasteur from the beginning of his experiments and led to the most ingenious inventions. To succeed in obtaining a pure culture how many difficulties had to be overcome! How could any one prepare sterile organic infusions if he did not know why they ended by changing under ordinary conditions? It is in the celebrated memoirs on organized corpuscles in the atmosphere and upon spontaneous generations that Pasteur has unraveled the causes of the alteration in organic infusions and laid the foundations of the fertile method of bacterial cultures.

We preserve piously in the Pasteur Institute some flasks containing fermentable liquids prepared by Pasteur himself in 1860 for the Commission of the Academy of Sciences before whom he had called his opponents. We may read still upon their yellowed labels the signature of the illustrious chemist Balard, reporter for the commission. After thirty-five years, these liquids are clear as on the first day and are witness of the certainty of the methods of Pasteur.

The culture of microbe-ferments led to the culture of microbe-viruses. The latter, it was thought, were formed only in living matter, proceeding from it by way of a chemical change. The new doctrine, on the contrary, regarded the viruses as parasites, developing in the body of the diseased animals, and capable without doubt of an independent life. The procedures which had succeeded with the ferments permitted also the culture of the viruses outside of the organism, in artificial media, where they multiply or swarm in successive generations, without ceasing to be deadly for man and animals. The culture of viruses in glass tubes, in a definite nutrient substratum, at the will of the experimenter, who becomes, so to speak, a gardener of microscopic pathogenic plants, constitutes the wonderful means of investigation which is to renew everything.

Thus prepared by the study of ferments, armed with a technique of incomparable surety, it would seem that Pasteur had only to attack contagious diseases. His thoughts, as a matter of fact, return without ceasing to this subject; but he was not a physician and he dared not advance upon a territory reserved to pathology. It was in spite of himself that he entered it in 1865. It required all the influence that Dumas had over him to decide him to do it; after much resistance, Pasteur, who had never dissected an invertebrate, never even touched a silkworm, set out accompanied by his faithful

assistants of the Normal School, Duclaux, Gernez, Raulin and Maillot, to study the disease which was destroying the silkworm industry of southern France and which extended into all the silk-growing countries. His hesitations once overcome, Pasteur set about the work with an ardor which finally ended in compromising his health.

Cornalia and other scientific men after him had found, long before, in diseased worms little oval corpuscles visible under the microscope. But from this observation nobody had drawn any conclusions by way of avoiding the disease or of curing it. Pasteur devotes himself to these corpuscles: they are for him the parasite, cause of the disease. He sees them in the diseased worm, follows them into the chrysalis, and into the winged insect and also into the eggs laid by the latter. It is therefore the direct transmission of the corpuscles from the perfect form of the insect to the egg which renders the disease hereditary. To obtain healthy eggs it sufficed to separate the layings of each female and to preserve only the eggs from the perfect insect exempt from corpuscles. The exact observation of the facts led necessarily to procedures which saved the industry of silk-growing.

But those worms hatched from healthy eggs may become diseased if they are raised in infected localities, for the disease is contagious. It is contagious because the corpuscles pass into the excretions of the sick worms and penetrate with the foods into the digestive tubes of the healthy worms or are introduced into their bodies by scratches on the skin. Pasteur, in many experiments, obtained the contagion by means of food artificially contaminated.

How many teachings there are for human medicine in this study on the disease of the silkworm! This disease was no less mysterious in its cause and in its extension than the infectious diseases of man; like several of the latter it is hereditary and to explain it observers had not failed to invoke the epidemic genius, idiosyncrasies of the subject, etc. Without knowing anything of all these doctrines, a chemist, who knows how to look through a microscope and make experiments, shows that all this is reduced to a parasite transmitted by the diseased to healthy subjects and by parents to their descendants. The mystery of the contagion and of the heredity is thus explained.

The disease of *pébrine* is not the only one which ravages silkworms: it is often confounded with another disease, *flacherie*. Pasteur discovers that this latter is due to fermentation of the leaves of the mulberry in the digestive tube of the worm. The agents of this fermentation are microbes, a vibrio and an organism of a rounded form united into chains. The excretions of the diseased worms transmit the malady, which has the greatest analogy with

certain contagious diseases of man that also have their seat in the intestine. This disease is not hereditary, but it persists in the silkworm nurseries from year to year, although the eggs from which the worms are hatched may be exempt from the germ of the disease. This means that the vibrios of flacherie remain alive in the dry dust. These vibrios produce in their interior shining corpuscles like those already seen by Pasteur, in 1860, in the butyric vibrio. These corpuscles are the eggs of the vibrio; of an incredible resistance to heat and drouth, they perpetuate the species; to-day we call them *spores.* It is the first example of a spore in a pathogenic microbe and the rôle of this very resistant production in the transmission of diseases that appear only after a long time has not escaped Pasteur.

The book on the diseases of silkworms is a veritable guide to whoever would study contagious diseases. Nevertheless how few physicians had read it in 1876! Pasteur did not fail to say to those who entered his laboratory and whom he took for collaborators: "Read the Studies on the silkworm; it will be, I believe, a good preparation for the labors you are to undertake."

The disasters of the war of 1870 were very grievous to Pasteur and it was with a patriotic thought that he busied himself with the beer industry, in which heretofore Germans had been without a rival. His "Studies upon Beer" made of brewing a scientific industry; but their reach exceeds by far what the title would lead one to suppose. The chapters on the origin of ferments, on life without air and fermentation, the diseases of beer, are filled with new general ideas, as suggestive for the biologist and the physician as they are useful to the brewer.[2] Nevertheless the doctrine of Pasteur penetrated little by little into medicine; the success of Lister and of his pupils carried conviction and, more and more, audacious persons described microbes in infectious diseases.

With what attention Pasteur followed these first labors! They rejoiced him and they vexed him at the same time: These experiments of physicians appeared to him often defective, the methods seemed to him insufficient and the proofs not rigorous, suitable rather to compromise the good cause than to serve it. Soon he could not endure it and resolutely he set himself also to the study of anthrax.

Rayer and Davaine had described in 1850 in the blood of sheep which died of anthrax little transparent motionless rods. After reading the memoir of Pasteur on butyric fermentation Davaine, in 1863, recognized that these little rods are parasitic microbes which constitute the inoculable virus of the disease; he gave to them

[2] Pasteur was aided in his studies on beer by Gayon, Grenet and Calmette.

the name of *bactéridie charbonneuse*. Then Dr. Koch (since become so celebrated) saw the bactéridie multiplying outside of the organism in drops of the aqueous humor obtained from the eyes of rabbits; he succeeded in obtaining as many as eight successive cultures. The bactéridie of this eighth generation, inoculated into animals, gave them fatal anthrax.

We do not very well understand to-day how after these experiments one could deny that the bactéridie were the cause of anthrax. But in 1876 the minds of men were not prepared for the idea that the viruses are parasitic microbes. For the greater number of medical men the bactéridie were only an accessory of the disease. "But in the blood of animals attacked by anthrax," they said, "the rods of Davaine do not exist alone; by the side of them there are globules and the blood plasma which contains the true amorphous virus; the cultures of Dr. Koch do not suffice any more to convince us. In the drop of aqueous humor which he sows with the blood from the animal, diseased by anthrax, M. Koch brings at the same time as the bactéridie the virus contained in the plasma; and the successive sowings which he makes in drops of the liquid simply lead to a dilution of this virus. Now do we not know that it is the property of viruses to act in infinitely small doses and that they may be diluted prodigiously without extinction of their activity?" At the time when they were made these objections appeared full of force.

Such was the state of the question at the time Pasteur attacked the problem. He also made cultures of the bactéridie; but instead of sowing the anthrax blood in a drop of nutrient media he introduced it into a flask which contained hundreds of cubic centimeters of an organic infusion where the bactéridie multiplied in some hours. With a trace of this first culture he sowed a second culture and in like manner up to the twentieth and even to the hundredth generation. A little drop of this hundredth culture gives anthrax as certainly as does the blood of an anthrax diseased sheep. Here one may not invoke dilution of the virus; the primitive droplet has been drowned in oceans; what does there remain of it in this hundredth culture, mortal, nevertheless, in the most minute doses? The virus, therefore, reproduces itself. It is, therefore, a living being; it can be only this bactéridie which exists alone in the culture flasks. It is indeed that which kills and not chemical substances which accompany it. Let us place, in fact, one of these flasks which contain it in a place at a rather low and constant temperature, in the cellars of the observatory as Pasteur has done; all the bacteria in suspension soon fall to the bottom of the flask. The clear supernatant liquid, injected into animals, even in large quantities does not make them sick, while a little of the bacterial deposit introduced into

their bodies destroys them with anthrax. These simple demonstrations were possible only on account of a perfect technique. Pasteur and his collaborator Joubert made use of that which had so well succeeded in the fermentations. It was no more difficult for them to prepare a hectoliter of sterile nutrient media than to obtain some cubic centimeters. Their procedures are so sure that in a long series of cultures the bactéridie remain pure without any error being able to cause the result to be suspicious.

If the bactéridium is the cause of anthrax, its properties should enable us to understand the etiology of the disease. Davaine had very well understood that the new notions would not be definitely victorious unless they explained how the animals took the anthrax in the fields, how they there came across the bactéridium, how it later penetrated into them and finally why certain fields were ravaged, while others, quite near, were spared by the disease. The preponderant rôle that Davaine attributed in the propagation of the disease to flies, which settle on the bodies of the dead animals, left without explanation the most characteristic circumstances of the epidemics. His adversaries very soon caused him to see clearly that: "this theory does not explain all, therefore it does not explain anything." Davaine did not have a certain bit of knowledge without which the etiology of anthrax remains incomprehensible; that of the anthrax spore. The spore of anthrax was discovered by Koch, who saw it form in the bacterial filaments cultivated in contact with the air. This spore resists drying and heat, and the greater number of agents which destroy the bactéridie when in the form of rods. It is the resistant form of the microbe and it perpetuates the species.

For Pasteur, it perpetuates also the disease in the anthrax country. Had he not already seen germ-corpuscles of the vibrio of flacherie preserve themselves in the dust of silkworm nurseries and carry over the disease from one year to another? First of all, by experiments in the laboratory he showed that sheep which ate the spores along with their food contracted anthrax and showed the symptoms and lesions of the natural disease.

This anthrax spore should exist in the anthrax territories, it must be discovered there. It was not an easy enterprise, that of isolating some spores of anthrax from among the millions of microbes contained in each parcel of cultivated earth; it was successful, however, by putting to use the properties which the anthrax spores possess of enduring a temperature of 80° to 90°, which temperature kills the greater part of the microbes of the soil. Some of the soil of Beauce, classic land of anthrax, is put into suspension in water; the finest particles are gathered, heated to 80° and inocu-

lated into guinea pigs: some of which die of anthrax. It is, therefore, certain that the sheep in Beauce find the germs of anthrax in the pasture fields. But where do these germs come from? They come from the dead bodies of animals that the shepherds, following custom, bury in the open field where the beast has fallen dead. The filamentous bactéridie, innumerable in the blood, are carried with it into the aerated earth of the graves and thanks to the summer heat there rapidly form their spores.

From all these facts there results a very simple prophylaxis for anthrax. Do not bury the dead bodies of anthrax animals in the fields, but destroy them or bury them in restricted places. The soil of the pasture being no more provided with spores will cease to be dangerous.

This is what Pasteur never ceased to say to the farmers of Beauce, with whom he went to observe and to make experiments, for this etiology of anthrax has been established in the heart of the anthrax territory in the midst of shepherds and flocks. All this did not prevent contradictors from accusing Pasteur of being only a laboratory man, of seeing things over his retorts and his bouillons and not as they are in nature and in practice.

During several successive years, at the end of July, the laboratory of Ulm Street was abandoned for Chartres. Chamberland and I went there to live in company with a young veterinarian, Vinsot. We found there as guide M. Boutet, who knew his anthrax country better than anybody else, and we met there sometimes M. Toussaint, who studied the same subject we did. Every week Pasteur came to give directions and to follow the work. What pleasant remembrances these campaigns against anthrax in the land of Chartrain have left us! Beginning in the early morning, visits to the sheep pastures scattered over this vast plain of Beauce resplendent in the sun of August, autopsies performed in the knacker's yard in Sours, at M. Rabourdin's place or in the courtyard of the farms; after noon, drawing up of the experimental notes, letters to Pasteur, then the commencement of new experiments. The day was well filled and how interesting and salutary was this bacteriology in the open air!

The breakfast at the Hotel de France did not last very long the days when Pasteur came to Chartres; we were soon in the coach going to M. Maunoury's in Saint Germain, who had courteously put his farm and his flock at our disposal. During the journey we spoke of the experiments of the week and of those to be undertaken. Pasteur, as soon as he had set foot on the ground, full of haste, went to the sheepfolds; standing motionless close to the enclosures he gazed at the experimental groups with that sustained attention

which nothing escaped; for hours he followed with his eyes the sheep he thought diseased; we had to remind him of the hour and to show him that the spires of the cathedral of Chartres began to disappear in the night before he was willing to go. He questioned the farmer and the laboring men and always took into account the opinion of the shepherds who, on account of their solitary life, gave all their attention to their flock and often became very sagacious observers.

No fact appeared insignificant to Pasteur; from things slightest in appearance he knew how to draw unexpected indications. In course of a walk in a field on the farm at St. Germain was thus born the original idea of the rôle of the earthworms in the propagation of anthrax. The harvest was over, there remained only the stubble. The attention of Pasteur was drawn to a portion of a field on account of the different color of the earth; M. Maunoury explained that the preceding year they had buried in that place some sheep dead of anthrax. Pasteur, who always examined things very closely, noticed on the surface of the soil a multitude of little mounds of earth cast up by earthworms. The idea then occurred to him that in their continual journeys from the depths to the surface the worms would bring to the surface earth rich in humus which surrounds the dead body and with it the anthrax spores that it contains. This explains why the germs of the disease persist such a long time in the fields, although so many causes tend to make them disappear: they are brought to the surface of the graves by the incessant bringing up of deep earth. Pasteur never stopped with conceptions; he passed immediately to experiments. The latter justified his previsions. I remember, among others, demonstrations made before Villemin, Davaine and Bouley. The latter had brought worms that had fed on the earth of a grave where the bodies of animals dead of anthrax were buried several years before. The earth taken from the intestine of one of the worms when inoculated into guinea pigs gave them anthrax.

These researches on the etiology of anthrax will remain a model. Never hitherto had medicine known a like perfection in the experiments, a like rigor in the deductions and such a certainty in the applications. Pasteur knew very well that the decisive battle was on and he neglected nothing to make the victory certain. Not content with supporting all that he advanced with irresistible proofs, he desired to leave nothing obscure in the labors of others; he takes one by one the facts which seemed opposed to his doctrine and shows, sanely interpreted, that they confirm it and this work of control gives him the occasion for new discoveries.

It is thus that he goes over the experiments by which MM. Jaillard and Leplat had for a moment menaced the conclusions of

Davaine. Anxious to study anthrax, these experimenters had requested virus from Chartres. Blood of a cow diseased by anthrax was sent to them; they inoculated it into rabbits who died without showing bactéridie in the blood, and nevertheless this blood inoculated into other rabbits destroyed them. They conclude that the bactéridium is not the true virus of anthrax, since the disease may exist without it. Davaine examined these facts, recognized that the animals of Jaillard and Leplat had not succumbed to anthrax but to another disease. The conclusion of Davaine is perfectly correct; it does not dissipate all the obscurities, for it does not explain how anthrax blood inoculated has been able to cause a disease which is not anthrax. Pasteur, aided by MM. Joubert and Chamberland, is going to show us what takes place in the experiments of Jaillard and Leplat and at the same time disclose to us unexpected facts of the highest importance. When an animal, sheep or cow, is attacked by anthrax, its blood collected at the moment of death swarms with the bactéridie and gives with certainty anthrax to the animals into which it is inoculated. But already after some hours, especially in the heat of summer, putrefaction takes place, the microbes of the intestine invade the deep veins and then the other vessels. At this moment, the blood contains the bactéridie of anthrax no longer in a state of purity; with them is associated another microbe, a motile vibrio, which is always the first to pass from the intestine into the vessels. This vibrio is very deadly to rabbits; it kills them more quickly than the bactéridie. If, therefore, we inoculate a rabbit with blood taken from an anthrax cadaver some hours after death, the rabbit receives at the same time bactéridie and vibrios. It dies either of a mixed disease caused by the simultaneous development of the two microbes, or, more often, of a pure septicemia because the vibrio, multiplying more quickly than the bactéridium, eliminates it by a living competition. The septic vibrio swarms especially in the peritoneum and rarely invades the circulation until after death. These peculiarities explain to us how Jaillard and Leplat, having asked for anthrax blood from Chartres, have received septic blood and why in the blood of their animals they have not seen under the microscope the rods of Davaine any more than the septic vibrio which is found there only in small numbers.

This septic vibrio is an anaerobic organism like the butyric vibrio studied by Pasteur in 1861. It is killed by oxygen when it is in a filamentous state, but it produces spores which resist the air. It constitutes the first example of an anaerobic pathogenic microbe, and the procedures which have served for its cultivation will be later put to use in the study of other microbes living without air, such as those of tetanus and symptomatic anthrax.

This justly celebrated note by Pasteur, Joubert and Chamberland on septicemia and anthrax introduced into science the notion, since become very important, of microbial associations and also the idea of bacteriotherapy. We read in it, in effect, that when the anthrax bactéridie are inoculated along with certain other bacteria into animals, the latter may not take anthrax and that this observation will be perhaps the point of departure for therapeutic applications.

The experiments of Pasteur establish not only facts, they suggest especially ideas. Witness those of the chicken attacked by anthrax which caused such a great quarrel with M. Collin. Fowls are absolutely refractory to anthrax. Nevertheless, Pasteur, Joubert and Chamberland rendered them susceptible by lowering their temperature, which is 42° C., to 38° C. by immersion in water. It is the condition necessary and sufficient to enable the inoculated bactéridie to multiply in the body of the fowl. On the contrary, the fowl, chilled and inoculated, returns to health if it is again warmed. Is not this new receptivity, created by a simple chilling, an interesting fact? Does it not give the explanation of the rôle of circumstances, to all appearances harmless, in the appearance of a disease?

In spite of all these labors followed in the laboratory, Pasteur still finds time to go to the hospital to collect material for new researches. Chamberland and I assisted him in these studies. It was to the Hospital Cochin or to the Maternity that we went most often, transporting into the corridors or into the amphitheater our culture tubes and our sterilized pipettes. One can hardly imagine the repugnance Pasteur had to overcome in order to visit the sick and assist in autopsies. His sensibility was extreme and he suffered morally and physically the pains of others; the stroke of a bistory which opened an abscess made him tremble as if he had received it. The sight of dead bodies, the sad need of autopsies, caused in him a veritable disgust. How many times we have seen him come out of these hospital amphitheaters sick! But his love of science, his curiosity for the truth, were stronger; and he came back the next day.

In the pus of warm abscesses and in that of furuncles a little rounded organism was found arranged in heaps which was easily cultivated in bouillon. It was found in infectious osteomyelitis of children. Pasteur affirmed that the osteomyelitis and the boil are two forms of one disease and that the osteomyelitis is the boil of the bone. In 1878, this assertion caused many surgeons to laugh.

In the puerperal infections, the pus of the uterus, of the peritoneum, and the clots in the veins contain a microbe of rounded

elements arranged in chains. This appears in the form of a rosary, which is especially evident in the cultures. Pasteur did not hesitate to declare that this microscopic organism is the most frequent cause of the infections in lying-in women. One day, during a discussion on puerperal fever at the Academy of Medicine, one of his most distinguished colleagues held forth eloquently on the causes of epidemics in the maternity hospitals. Pasteur interrupted him from his place: "That which causes the epidemic is not at all what you have said; it is the physician and his assistants who carry the microbe from a sick woman to a healthy woman." And as the author replied that he very much feared this microbe would never be found, Pasteur hurried to the blackboard, drew the organism in the form of a chain and said, "That is the way it looks." His conviction was so strong that he could not prevent himself from expressing it forcibly. We can hardly understand to-day the surprise and even the stupefaction in which he put physicians and students when at the hospital, with a simplicity and an assurance which appeared disconcerting in a man who entered for the first time as an assistant at a labor, he criticized the methods of dressing and declared that all the linens ought to be put through the sterilizing oven. In addition to all this, he claimed that he was able to determine by examination of the lochia of the women which ones would have the fever, and he asserted that in the badly infected women he would demonstrate the microbe in blood taken from the finger. And Pasteur did as he said he would. In spite of the tyranny of medical education which then weighed heavily upon men, some pupils were attracted and came to the laboratory to see more closely those methods which resulted in diagnostics so precise and prognostics so certain.

Pasteur never gave botanical names to the microbes which he discovered: he designated them after some peculiarity of their form or of their manner of growth. Thus the microbe of the boil was for him the microbe of clumped grains, that of puerperal fever, the microbe of grains in the form of a rosary. It is these which, under the more regular names of Staphylococcus and of Streptococcus pyogenes, have made such a great highway in bacteriology, as we know it.

Pasteur is again a forerunner when he undertakes with M. Joubert the bacteriological examination of waters which since has led to the saving of so many human lives.

Generally, the infectious diseases do not occur a second time. Is it the same with anthrax? How shall one determine it since it appears certain that every attacked animal soon dies? Nevertheless, among the sheep inoculated in the course of the experi-

ments made at Chartres, some had resisted, while their companions were dead. The idea came that perhaps in the fields of Beauce, so much exposed to anthrax, those sheep which survived had formerly contracted the disease and had recovered from it, this first attack having given them immunity. Some experiments, undertaken by Pasteur and Chamberland, with another purpose in view justified this hypothesis. A veterinarian of Jura had proposed a remedy against anthrax in cattle; to verify the efficacy of it the cattle were inoculated; one half were treated, the other half were kept as controls. In each one of the lots there were cattle which died and others which survived, although they became very ill. Having recovered, these last, without noteworthy disease, endured virulent anthrax inoculation which killed new cattle. The first attack had given them immunity; it is therefore possible to render cattle refractory to anthrax.

This question of immunity dominates the entire history of infectious diseases; Pasteur was led back to it without ceasing by his experiments. He thought of it all the time. The Jenner vaccination was especially the subject of his meditations. What relation is there between the vaccine and the smallpox? Why has Jenner's vaccination remained an isolated fact in medicine? We are ignorant of the nature of the virus of smallpox and of the vaccine virus. But there are viruses which we know better. Would it be possible to find vaccines against them? From our first entrance into his laboratory Pasteur said to us without ceasing, that is, to Chamberland and to me: "We ought to be able to immunize against the infectious diseases the viruses of which we can cultivate." Haunted by this idea, how many impossible experiments have we not gravely discussed, to laugh at them next day, during this laborious period which preceded the discovery of the attenuation of viruses!

The latter was realized in a disease of fowls, the chicken cholera. The microbe of this disease multiplies readily in bouillon made from the muscles of fowls. A young culture is extremely deadly: it kills all the fowls which receive even the least quantity of it under the skin. Kept in a thermostat at 37° C. in contact with the air, this culture loses little by little its activity. After a certain time, inoculated into chickens, it only kills now and then one; at the end of a longer time, it no longer kills them but it makes them ill; finally, it becomes so inoffensive that it produces in them only a slight fever. These fowls, once recovered, will then endure the inoculation of the most virulent virus, mortal for new fowls. It does not kill them, they have acquired immunity.

This experiment therefore realized the artificial attenuation of a virus and preventive vaccination by means of this attenuated virus.

The cause of the attenuation is the prolonged action of air upon the virus, at a suitable temperature. In fact, the same culture which becomes attenuated in the air keeps its virulence in a sealed tube to which air does not have access.

The attenuated viruses, thus prepared, may reproduce themselves for successive generations, transmitting their qualities to their descendants. Attenuation is *hereditary*. The viruses are microscopic plants; they may be modified by culture just like the higher plants. Pasteur has obtained races of virus, as the gardeners obtain races of plants. The methods which gave the vaccine for cholera of chickens have furnished those for anthrax, for rouget of hogs and for still other diseases.

In the preparation of the anthrax vaccine, in the very beginning, difficulty was encountered. The attenuation of the virulence is produced by prolonged action of the air upon the microbial cell. But this cell is modified only so long as it remains in a vegetative state; in this form it is more sensitive to the diverse influences which act upon it. It is not at all the same when the cell forms spores. The agents which modify the vegetative cells have no influence upon the spores, which are much more resistant. The cultures of chicken cholera never give spores; consequently they become attenuated easily. Those of anthrax, which produee spores, remain indefinitely virulent. To attenuate the anthrax bactéridie, it is therefore necessary to prevent them from forming spores. This end was reached by cultivating them at the temperature of 42½ to 43° C.; at this temperature, after the action of oxygen, the attenuation takes place little by little, so that we obtain a series of viruses of diminishing activity by drawing at various times from the culture originally kept at 37° C. These attenuated bactéridie preserve their weakened virulence through successive generations cultivated at 30° to 40° C.; and at this temperature they give once more spores, which fix this virulence. We have thus a whole scale of virus more and more feeble, and which can be reproduced at will. There remains only to choose in this series a culture which, inoculated into animals, gives a slight disease, but one which is sufficient to confer upon them immunity.

The individuals of the same species present very great differences with respect to their resistance to anthrax; consequently, in practice, we make two vaccinations with a twelve days' interval, the first with a feeble virus, the second with a stronger virus, which completes the immunity.

Preventive vaccination against anthrax entered at a bound into practice. The Society of Agriculture of Melun proposed to Pasteur a public trial of the new method. The program was ar-

ranged for the 28th of April, 1881. Chamberland and myself were on our vacations; Pasteur wrote to us to return at once, and when we were together in the laboratory, he told us what had been agreed upon. Twenty-five sheep were to be vaccinated and then inoculated with anthrax at the same time as twenty-five control sheep; the first would resist the disease, the second would die of anthrax. The terms were precise, no place was left for the unexpected. When we remarked that the program was severe, but that nothing more remained than to carry it out as agreed upon, Pasteur added, "What succeeded in fourteen sheep in the laboratory will succeed just as well in fifty at Melun."

The animals were herded at Pouilly-le-Fort, near Melun, on a farm of M. Rossignol, veterinarian, who had proposed the experiment and who was to supervise it. "Especially do not make any mistake in the flasks," said Pasteur gayly, when on the fifth of May we left the laboratory to make the inoculation with the first vaccine.

The second vaccination was performed the seventeenth of May, and each day Chamberland and I went to visit the animals. In these repeated trips from Melun to Pouilly-le-Fort, many observations reached our ears, which showed that the multitude did not believe in our success. Farmers, veterinarians, physicians followed the experiment with a lively interest, some even with passion. In 1881 the science of microbes had very few partisans; many thought that the new doctrines were baleful and regarded it as an unexpected opportunity that they had been able to draw Pasteur and his assistants out of the laboratory to confound them in the open air, in a public experiment. Here was a chance to be done with these compromising novelties in médicine and by a knock-out blow to find again security in the same traditions and the ancient practices menaced for a moment.

In spite of all the passions which arose around them the experiment followed its due course. The trial inoculation was made the thirty-first of May and the second of June was the date set for the return to determine the results. Twenty-four hours before the decisive time, Pasteur, who had gone on with such perfect confidence in the beginning of the public experiment, began to regret his audacity. For some moments his faith was shaken, as if the experimental method might betray him. A too continuous tension of his mind had led to this reaction, which moreover lasted but a short time. The next day, more certain than ever, Pasteur went to confirm the striking success which he had predicted. In the crowd which thronged about him that day at Pouilly-le-Fort, there were no longer any incredulous persons, but only admirers.[3]

[3] The results were perfectly clear-cut; all the vaccinated sheep lived, all the unvaccinated ones died.—E. F. S.

It is now fourteen years since anthrax vaccination has been subjected to practical tests: wherever it has been applied the losses from anthrax have become insignificant. It was followed by a vaccination against measles in swine, in which our poor comrade Thuillier has particularly labored.[34] But these immediate results are the least merit of the Pasteurian vaccination; they have given an immense confidence in a science which obtained such a success and provoked such an irresistible movement. Especially they have inaugurated that series of researches upon immunity which must finally lead us to an efficacious treatment of infectious diseases.

Virulence is a quality that microbes may lose. They may also acquire it. If we met in nature this anthrax organism attenuated to the point that it would no longer kill any animal, certainly we should not recognize it for the virus of anthrax. It would appear to us to be a saprophytic microbe. One must have assisted in all the phases of its attenuation to know that this inoffensive bacillus is the descendant of a redoubtable virus. We may nevertheless restore to it the virulence which it has lost by inoculating it first into an extremely susceptible being, a mouse only one day old. Cultivated in the body of this very young mouse, the bacteridium recovers its parasitic aptitude. If with the blood of this mouse we inoculate another a little older it will perish. By passing thus from younger to older mice, we finally succeed in killing adult mice, guinea pigs, then rabbits, then sheep, etc.

During these passages the virulence has gone on increasing. This increase of virulence, which we obtain experimentally, takes place without doubt in nature and we can imagine very well that an ordinary microbe harmless for an animal species may become deadly to it. Is it not in this manner that in the course of the ages the infectious diseases have appeared?

From these modifiable viruses which are so plastic that the experimenter, so to speak, shapes them to his will, it is a far cry to the ancient conception of virulent entities! Pasteur's note on the attenuation of the viruses and the return to virulence was presented to the Academy of Sciences the twenty-eighth of February, 1881. Better than any other it gives the measure of Pasteur and makes us understand the extraordinary penetration of his mind.

The researches on anthrax did not occupy all Pasteur's time. During the same period he began studies upon rabies. This disease is one of those which take the fewest victims among men; if Pasteur chose it as the subject of studies it was because the virus of rabies has always been regarded as the most subtle and the most mysterious of viruses, and also because hydrophobia is for every-

[34] T. lost his life studying cholera in Egypt.—E. F. S.

body the most dreaded and frightful disease. Pasteur shared the common horror; and believed that to solve the question of rabies would be a benefit to humanity and a striking triumph for his doctrines.

In 1880 the first experiments were undertaken. Rabies is inoculable into animals, it is therefore accessible to experimentation; no doubt it is caused by a microbe, and he did not question that the methods which had led to the discovery of so many other viruses would succeed also in demonstrating that of rabies. But it was not so: not only have we never been able to cultivate the microbe of rabies, but no one has succeeded in seeing it. The most patient investigations with the microscope, the most advanced methods of staining have miscarried up to this time.[4] It was necessary to work upon a virus which could not be cultivated and was invisible, and nevertheless we have succeeded in establishing a prophylaxy for rabies, after the bite, the results of which exceed by far the most successful that have ever been obtained in medicine. Is there a more striking example of the power of the experimental method applied to things medical? Rabies is transmitted by the bite of a mad animal, because the virus is contained in the saliva. But inoculations made with the saliva do not give the disease with any certainty; even when they succeed, the latter appears only after an incubation period which is often prolonged during several months. The first step was to learn how to give rabies with certainty; in order to do that it was necessary to give up inoculation with saliva, which, in addition to the rabic virus, contains a large number of common microbes, sometimes hindering its action. Where then should one find in a rabic animal the virus in a state of purity? Rabies is manifestly a disease of the nervous system; perhaps the virus is in the nervous centers. In fact, experiment shows that the true seat of the rabic virus is the brain and the spinal cord. The inoculation of the substance of these organs, taken from a rabid animal, gives the disease with more certainty than the saliva, because the virus is there more abundant, and especially because it exists there in a state of purity. Nevertheless, it is not sufficient to have a pure rabic virus in order to give the disease immediately. The inoculation of the substance of the rabic brain under the skin is not always followed by rabies, and when the latter does occur, it appears most often only after a long incubation period. Subcutaneous inoculation therefore is not to be trusted. Then the idea came that to transmit rabies with certainty the virus should be deposited in the nervous centers, since it is there that it grows best. It was therefore decided that a dog should be inoculated under the dura mater by trepanning the skull.

[4] Rabies is now generally believed to be due to the Negri bodies.—E. F. S.

Ordinarily as soon as an experiment was conceived and discussed it was set in operation without delay. This one, upon which we nevertheless counted so much, was not at once executed; Pasteur, who must sacrifice so many animals in the course of his beneficent studies, experienced a strong repugnance to vivisection. He assisted without too much squeamishness at a simple operation like a subcutaneous inoculation, and yet, if the animal cried a little, Pasteur was immediately full of pity and gave to the victim consolations and encouragements which would have appeared comic if they had not been touching.

The thought that it was necessary to bore through the skull of a dog was disagreeable to him. He earnestly wished that the experiment might be realized, but he feared to see it undertaken. I did it one day when he was absent. The following day, when I reported to him that the intracranial inoculation did not offer any difficulty, he was full of pity for the dog: "Poor beast, its brain without doubt is injured, it must be paralyzed." Without replying I descended to the basement to find the animal and brought it into the laboratory. Pasteur did not love dogs; but when he saw this one full of vivacity nosing about curiously he expressed the liveliest satisfaction and lavished upon it the most amiable words. Pasteur felt a great tenderness for this dog who had so well endured trepanation and had thus removed all his scruples against future trepanations.

This first trepanned dog took rabies characteristically in fourteen days. The experiment, repeated a great many times, gave the same result; it was possible therefore to give rabies with certainty and in a relatively short time; consequently it was easy to experiment with it.

The inoculation of rabic virus by trepanation succeeded also in the rabbit, and it is easy to transmit rabies in this manner from rabbit to rabbit. During these successive passages the virus is strengthened and the duration of the incubation diminished to a period of only six days. In this way we obtain veritable intracranial cultures of the rabic virus. Instead of making the culture in artificial media, as in case of other viruses, we make that of the rabic virus in living material. These cultures in the substance of the nerves may be modified like the cultures of anthrax or of the chicken cholera.

The rabic spinal columns, exposed to the action of the air, in an atmosphere deprived of moisture, dry out and lose their activity. After fourteen days the virus is weakened to that degree that it is inoffensive even in the strongest doses.

A dog which receives this spinal cord fourteen days old, then on the next day a cord thirteen days old, then that twelve days old,

and so on till he receives a fresh cord, does not contract rabies, but he has become refractory to it. Inoculated in the eye or in the brain with the strongest virus he remains well. It is therefore possible, in fifteen days, to give immunity to an animal against rabies. Now men bitten by mad dogs do not ordinarily contract rabies sooner than a month and often more after the bite. This incubation period may be utilized to render the bitten person refractory to the disease.

Experiments made upon bitten dogs or inoculated ones succeeded beyond expectation. You will remember how, with the aid of MM. Vulpian and Grancher, it was extended to man. More than sixteen thousand persons have undergone to-day antirabic treatment and the mortality of these treated persons has been less than one half of one per cent.

The discovery of the prophylaxy of rabies brought about everywhere a veritable enthusiasm. It did more for the popularity of Pasteur than all his previous labors. In return for such a benefit, the great public wished to manifest its gratitude in a fashion worthy of itself and of him who was the object of it; it was then that a subscription was opened which laid the foundations of the Pasteur Institute.

It seems that those results acquired in the study of rabies might have presented themselves naturally to the experimenter and in a logical order. One must have participated in this study to know what stubborn labor it necessitated during more than five years. Pasteur displayed therein that tenacity of purpose which leads to success. How many times, in the presence of unexpected difficulties when we could not imagine any way out, I have heard Pasteur say: "Let us do over the experiment, the essential thing is not to be discouraged."

After the studies on rabies, the health of Pasteur continued to decline. He supported better the obstinate labor of the period of researches than the emotions of the triumph. Pasteur welcomed gladly the demonstrations and the universal gratitude lavished on him, not through a vain love of praise, but on account of the honor which accrued from them to his country, to science and to his loved ones.

The numberless manifestations of which he was the object at this period excited his sensibility even to tears. As soon as the preventive inoculations were applied to man all repose was lost for him. Every bitten person brought him a new preoccupation. The sight of wounded children especially caused him emotions which he could not control. When desperate cases supervened against which no method was of any avail, Pasteur suffered all the torments of

these diseased ones. Every visit he made to them was for him a torture, and he could not help visiting them. It was necessary to get him away from Paris. He was in Italy when those attacks appeared against the antirabic method which made so much noise at the epoch and which are so thoroughly forgotten to-day. He felt them at a distance and was keenly afflicted by them. From this time, Pasteur had to renounce the life of the laboratory; for such a worker as he was, the inaction was a sorrow. Only the visits of his collaborators and the company of his grandchildren were capable of restoring to him a little gaiety. The never-to-be-forgotten ceremony of his Jubilee, in December, 1892, by showing him what a place he held in the esteem of scientific men and in the veneration of peoples, caused him to experience a profound emotion. From that time on Pasteur lived only in the love of his own people; all the care and all the affection with which he was surrounded was necessary to keep him alive, he was so feeble. But even to the end, his thought was in the laboratories, with those who labored strenuously in order that the foundation which bears his name might remain worthy of him. These labors on anthrax, the attenuation of virus, the swine fever, rabies, Pasteur accomplished them in less than ten years, from 1876 to 1885, with the aid of only a few collaborators, M. Joubert at first, and then MM. Chamberland, Thuillier and Roux. Those years passed in the laboratory of rue d'Ulm during this period of discoveries remain present in my mind as the best ones of my life. In order to be nearer the work, master and disciples lived in l'École Normale. Pasteur was always the first to arrive; every morning, at 8 o'clock, I heard his hasty step, a little trailing [on account of his paralysis] over the loose pavement in front of the room which I occupied at the extremity of the laboratory. As soon as he had entered, a bit of paper and a pencil in his hand, he went to the thermostat to take note of the state of the cultures and descended to the basement to see the experimental animals. Then we made autopsies, cultures and the microscopic examinations. One must have seen Pasteur at his microscope to have an idea of the patience with which he examined a preparation. Moreover, he looked at everything with the same minute care; nothing escaped his myopic eye, and we said jokingly that he saw the microbes growing in the bouillons. Then Pasteur wrote out what had just been observed. He left to no one the care of keeping the experimental records; he set down most of the data which we gave him in all its details. How many pages he has thus covered, with his little, irregular, close-pressed handwriting, with drawings on the margin and references, all mixed up, difficult to read for those not accustomed to it, but kept nevertheless with extreme care. Nothing was

set down which had not been established; once things were written, they became for Pasteur incontestable verities. When, in our discussions, this argument resounded, "It is in the record book," none of us dared to reply. The notes being taken, we agreed upon the experiments to be made; Pasteur stood at his desk ready to write what should be decided upon, Chamberland and I facing him, with our backs to a show-case (vitrine). It was the important moment of the day; each one gave his opinion, and often an idea, confused at first, became clear in the course of the discussion and ended by leading to one of those experiments which dissipated doubts. Sometimes we were not in agreement and the discussion was heated, but, with Pasteur, who passed nevertheless for the authority, one could say freely all his thought; I have never known him to resist a good reason.

A little before noon, they came to call Pasteur for the midday meal; from noon till two o'clock he came into the laboratory and the most often, on our return, we would find him motionless in front of a cage, never wearying of observing a guinea pig or an interesting rabbit. About two o'clock Madame Pasteur sent for him, else he would have forgotten to go to the Academy and to the committees of which he was a member. Then we spent the afternoon in making the experiments agreed upon, interrupting ourselves only in order to allow Chamberland to smoke a pipe. The master had a horror of tobacco and we smoked only in his absence. Pasteur returned toward five o'clock. He informed himself immediately of all that had been done and took notes; his notebook in hand, he went to verify the tickets fastened on the cages, then he told us the interesting communications heard at the academy and talked of the experiments in progress. It was at this moment that Pasteur revealed his thought most willingly, especially if we provoked him by objections; then his clear eye flashed more vividly; his speech, a little thick in the beginning, became more and more animated and persuasive. He developed the most profound and the most unexpected ideas, he proposed the most audacious experiments. This rigorous experimenter had a powerful imagination; for him *a priori* there was nothing absurd. But his most enthusiastic flights always led him to an experiment to be made and he retained only that which could be demonstrated. His ardor was so communicative that after having heard him the experimental projects filled the mind. When we got him going on the subject of his first labors, he expressed himself like a poet on molecular dissymmetry and its relation to the dissymmetric forces of nature. Those days, Pasteur forgot the dinner hour; and Madame Pasteur had to send for him two or three times, or come to find him herself; then he went away smiling and saying to us, "You are to blame, I shall be scolded."

The laboratory was always shut up; one was able to enter it only after having sounded at the great door, constantly closed. Visitors rarely got past the antechamber; when Pasteur was at work he was not receptive, even to his friends; to interrupt him was to make him unhappy. I see him turning toward the intruder, waving his hand as if to send him away, and saying in a supplicating and desperate tone: "No, not now, I am too busy." He was nevertheless the most simple and the most approachable of men, but he did not understand how any one could disturb a scientific man who is occupied in making laboratory notes. When Chamberland and I were pursuing an interesting experiment, he stood guard over us. Seeing at a distance, through the glass windows, the comrades who came to ask for us, he went himself to receive them and to turn them away. These whims of Pasteur showed so naïvely his sole preoccupation in the work that they never vexed anybody.

Pasteur has been reproached for not having opened widely his laboratory to students who might have spread his ideas and his methods; it has even been said that he loved to keep secret his methods of research. Nothing is more unjust; in his communications, Pasteur sowed with an open hand new ideas and every one has been able to profit by them. He was therefore an incomparable teacher; he has not advanced any idea without giving information enabling any one to control it; but instead of losing himself in useless details and explaining clumsily the arrangement of apparatus which everybody could easily imagine, he confined himself to stating exactly the necessary and sufficient conditions. The laboratory of the rue d'Ulm was not large enough to receive numerous investigators, there was just enough room for Pasteur and his assistants.[5] Moreover, Pasteur worked easily only in silence and retirement; near him he admitted only his collaborators; the presence of a stranger to his occupations sufficed to disturb his work. One day when we went to see Wurtz at l'École de médecine, we found the great chemist in the midst of his students, in his laboratory full of activity, buzzing like a beehive.

"How can you work," said Pasteur, "in the midst of such a disturbance?"

"That only stirs up my ideas," replied Wurtz.

"That would drive all mine away," replied Pasteur.

Pasteur was constantly imagining new experiments; he noted his projects upon sheets of a little notebook or upon morsels of card-

[5] In the laboratory reserved for *l'agrégé préparateur*, several persons have been admitted to work, notably M. Denys Cochin. Later, when the annex in the Rue Vauquelin was fitted up, Pasteur hastened to receive there Dr. Straus and then Dr. Grancher.

board which he carefully preserved. His left hand remaining useless after the paralytic attack of 1868, he confided the execution of experiments to his assistants; an irreproachable experimenter himself, he showed himself very exacting toward others. For him, there was no impossible experiment: when we observed that that which he demanded of us presented very especial difficulties he said, "That is your affair; do it in any way that seems best to you, provided it is well done." And he satisfied himself always that it was well done; he separated out the good from the bad with admirable sagacity.

A communication of Pasteur to the Academy of Sciences or to the Academy of Medicine was an event; because he published nothing that was not finished. Each one of his notes takes up only some pages of the *Comptes rendus*, but it contains the substance of hundreds of experiments. Consequently we can read them and reread them, and always find there something of use; often a simple phrase indicates a new pathway, and several of those which are thus noted have not yet been traversed. All Pasteur is in his writings; his imagination reveals itself therein by the profundity and the audacity of the generalizations, by the rigor of his spirit, by the justice of his views, by the soundness of his conclusions and his enthusiasm by the emotion of his language.

Before writing, Pasteur read and reread the experimental notebooks, then he dictated to one of us or more often to Madame Pasteur. He kept the manuscript sometimes during weeks, retouching it without ceasing; when he was satisfied, he read it to us and discussed with us its phraseology; often he received our comments with impatience; but he always took them into account if they were just. Madame Pasteur recopied it in her fair handwriting, so easy to read; Pasteur would never have sent to the publisher a manuscript full of erasures; if he modified some passage he glued over these lines gummed paper, cut to the proper dimensions, and wrote it anew. During all this work of editing, the question under treatment developed singularly, and we, the collaborators of the master, who knew at what point the experiments had abandoned him, were astonished to see it grow and be transformed in the final note.

The ideas of Pasteur were too new not to be opposed; besides, Pasteur did not fear strife; his discussions at the Academy of Sciences have remained celebrated; those which he maintained at the Academy of Medicine were more passionate still. Many physicians, in fact, and not the least conspicuous ones, saw at first with stupefaction and then with indignation this chemist overthrow with so much assurance medical doctrines. To study diseases in a laboratory with chemical apparatus was for them a medical con-

tradiction. On his part, Pasteur, persuaded that he brought the truth, would have believed it a bad action if he had not maintained his point with all his force. Hence those contests with which the heroic ages of bacteriology have resounded; every discovery of Pasteur has been imposed with blows; when he despaired of convincing his colleagues, he addressed himself over their heads to the public of young physicians who followed the lectures.

Under these contradictions he lost his serenity, and as he was sure of the propositions he advanced, he proposed willingly the nomination of academic commissions before whom he would bring his adversaries as before a tribunal.

So much courage and stubbornness rallied partisans to his doctrine, but there remained irreductible opponents who came back without ceasing to the charge. There is nothing astonishing in the fact that Pasteur and they could not understand each other. They were imbued with that medical spirit made up at the same time of skepticism and of respect for traditions. He had the faith of a novice and the assurance which the experimental method gives. He was indignant that any one could remain hesitant in the face of a demonstrative experiment.

He left these seances stirred to the depths; MM. Vallery-Radot, Chamberland and I often awaited him at the exit: "Have you heard?" he would say to us: "To the experiments they have replied with talk!" We returned on foot to the rue d'Ulm and his irritation gradually subsided; immediately he spoke of making still more experiments to throw additional light, for the contradictions excited him to make new researches. These tumultuous seances at the Academy of Medicine were therefore useful, since they were like a stimulant to the activity of Pasteur.

The passion of Pasteur for science carried him away sometimes in outbursts very amusingly naïve. For him, a man who made a bad experiment or a false reasoning was capable of anything. One day when he read to us in the laboratory a work which appeared to him to be particularly bad, he was exasperated and cried out: "A man who can write such stuff I would not be surprised if he should beat his wife," as if to beat his wife were the height of scientific irregularity!

The great force of Pasteur is that he could, without being weary, hold his thought concentrated upon the same object. He followed his idea without allowing himself to be distracted and he brought everything to it; thus from a conversation with persons even the most unfamiliar with science he knew how to draw something useful for his researches. Of him also one can say that he has made

his discoveries by continually reflecting on them. His stubborn thought attached itself to difficulties and ended by solving them as the intense flame of the blowpipe constantly directed upon a refractory body ends by melting it.

In those moments of great preoccupation, Pasteur remained silent, even in the midst of his own family. Nothing could efface the obstinate wrinkles of his countenance until the solution was found. Then his face became luminous, and this concentrated man allowed his joy to overflow, explaining what he had discovered and what he hoped from it. All those close to Pasteur and associated with his scientific life felt the rebound of his preoccupations and participated in the satisfactions of the savant.

One can not understand the career of Pasteur if he does not know of his family and especially of Madame Pasteur. From the first days of their common life Madame Pasteur understood what sort of a man she had married; she strove to remove difficulties from his life, taking upon herself the cares of the household in order that he might keep all the liberty of his spirit for his researches. Madame Pasteur has loved her husband to the point of understanding his work. In the evening she wrote under his dictation and brought out explanations, for she was really interested in the hemihedral facets and in the attenuated viruses. And then she had clearly perceived that ideas become clearer when they are explained and that nothing leads more certainly to the conception of new experiments than the description of those which have been made. Madame Pasteur was not only an incomparable companion for Pasteur—she was his best collaborator.

The work of Pasteur is admirable. It shows his genius, but one must have lived intimately with the master to know of the goodness of his heart.

BIOLOGICAL STATIONS FOR THE STUDY OF PLANTS AND ANIMALS TOGETHER

By WALTER P. TAYLOR

BIOLOGIST, U. S. BUREAU OF BIOLOGICAL SURVEY

THE world of nature is a unit. If it is upset or interfered with in one place the entire system is bound to be affected. Before man's appearance the animals and plants had undoubtedly attained a degree of equilibrium. But such human activities as reclamation of arid lands, grazing and lumbering have thrown the natural system off-balance, leading to unforeseen consequences in many directions which must be studied and controlled if man is to maintain himself and his civilization on anything like the present basis. As Lankester[1] puts it, civilized man has proceeded so far in his interference with extra-human nature, has produced for himself and the living organisms associated with him such a special state of things by his rebellion against natural selection and his defiance of nature's pre-human dispositions, that he must either go on and acquire firmer control of the conditions or perish miserably by the vengeance certain to fall on the half-hearted meddler in great affairs. We may indeed compare civilized man, as Lankester points out, to a successful rebel against nature who by every step forward renders himself liable to greater and greater penalties, and so can not afford to pause or fail in a single step.

In no provinces are disturbing consequences more in evidence than in forestry and grazing. Forests have been cut down and range-lands overgrazed with little thought of the future, until, already, the supply of those basic products, meat and wood, is threatened.

While the problems involved are plant problems, of course, there does not seem to have been any very wide appreciation of the fact that they are animal problems, too. A moment's review will, I think, show that investigations of animals no less than plants will be necessary to the accomplishments in forestry and grazing which are of such vital importance to the people. Among the animals of importance in this connection are, of course, representatives of various groups, ranging, doubtless, from the protozoa to man. I am limiting the present brief exposition principally to the mammals and especially the rodents.

[1] "Kingdom of Man," 1911, pp. 31–32.

Relations of Rodents and Grazing

Something is known as to the effect of the banner-tailed kangaroo rat and of the Zuni prairie dog on vegetation. The kangaroo rat has been found to be a champion hoarder, and stored food, principally the seeds and crowns of important forage grasses, and varying in amount from one sixth of an ounce to more than twelve and one half pounds, has been found in different dens. In one case approximately 680,000 separate cut sections of grass had been stored by this rodent, showing its extraordinary activity. The ground for a radius of 15 to 25 feet about the den may be practically denuded of vegetation. During periods of extreme drought the species may be of critical importance on grazing areas from the standpoint of carrying capacity of the range.

Studies by the Biological Survey and its cooperators of prairie dogs and range grasses in northern Arizona have shown that prairie dogs on certain areas consume a large proportion of the forage. Furthermore, these rodents are more destructive to grasses than are cattle, for they can crop more closely. In the absence of thoroughgoing control measures the prairie dog will undoubtedly be a strong factor in the ultimate destruction of all forage on vast areas of good stock range.

Some of these desert rodents, notably the kangaroo rat and pocket mouse, can go all their lives, apparently, without drinking water. The suggestion has recently been made that as the world dries up, mankind will ultimately be dependent on jerboas, jack rabbits and other drought-loving species. While this suggestion at present seems fantastic, we ought, as a matter of fact, to know a good deal more of the ecology and physiology of these rodents than we do.

Work already done on certain desert rodents is suggestive. We know very little of a definite and satisfactory character of the relation of jack rabbits, wood rats, pocket mice, grasshopper mice and various ground squirrels to grazing. Some may be harmful, some beneficial, and some neutral, in relation to the forage plants and valuable shrubs of the desert. All the burrowing rodents, even the pest species, may subserve an important and beneficial function in cultivating the soil and making it fit for the growth of plants. Man must of course protect the forage from pests, but he must have more facts regarding animals, their life histories and their relation to their surroundings, if he would avoid pitfalls in the application of control measures.

RODENTS AND THE FOREST

We in the United States are using up our forests more than four times as fast as they are being grown. The virtual end of our wood supply is in sight if we do not immediately increase our forest area and the rate of forest production. We can do this by keeping fire out of the forest, growing trees on the eighty-one million acres of land which were formerly forested but which are now a desolate waste, and by adequately maintaining the reproduction and growth of timber in such forests as remain.

In either artificial or natural reproduction of forest the rodent problem is a serious one. At the Wind River nursery[2] it was found that one mouse could eat three hundred seeds of the Douglas fir, and one chipmunk six hundred, in a single day. If 42,350 seeds were sown on an acre, ninety mice could consume the bulk of the seeds in one night and have only enough left for a light lunch the next night. In Arizona and New Mexico we have one of the largest continuous forests of western yellow pine in the west. Investigations at the Southwestern Forest Experiment Station, near Flagstaff, have shown that rodents are an important factor in yellow pine reproduction under natural conditions, and become even more important on cutover lands.

Nor is the case much better with planting, that is, the setting out of young trees raised in the nursery. The principal rodent offenders in connection with planting projects in the west appear to be rabbits, wood rats and pocket gophers. Rabbits girdle the young trees and sometimes eat the foliage. Wood rats cut off the young trees and carry them to their nests. Pocket gophers cut off the roots.

The actual or possible benefits of some rodent activities should not be overlooked. Quite often the rodent which eats tree seed scatters and plants it. Squirrel caches are recognized sources of pine and redwood seed. Hoffman says that the tree squirrel of the northwest is a furred forester of much importance and value, playing a leading part in the reproduction of the Douglas fir. During the summer of 1919, following the great Cispus burn of 1918, he found stands of up to 40,000 seedlings per acre. These little trees were from seeds buried in the forest floor by the squirrels and surviving the fire. Certain rodents may fill an important place in the natural economy of the forest as soil-makers and cultivators, as consumers of vegetation inimical to trees, as natural pruners of overfull tree crowns, or even as automatic thinners of overthick stands.

[2] Willis, C. P. "The control of rodents in field seeding," Proc. Soc. Amer. For., IX, pp. 365–379, 1914.

Forest scientists have been trying for some years to determine the factors limiting the distribution of forest trees. Results of the work of English ecologists clearly suggest that in some cases rodents may be a more critical factor in limiting forest distribution than climate or soil.

The importance of the study of forest rodents has been recognized by a number of leading biologists and foresters. The species of rodents in different localities are often not the same. The habits of each species are to a great extent peculiar, and the traits of the same animal may be unlike at different times of year. In one case a thorough poisoning in Montana was ineffective because the grain was distributed in hoarding season and stored without being eaten.

Conclusion

Thorough studies of plant ecology and of plants, their habits, life histories, acclimatization and uses are all too rare; but adequate provision for attention to problems on the animal side is lacking. The agricultural stations, colleges and universities are doing all too little on this head. The Carnegie Institution of Washington, while it is doing much work with plants, is not engaged in animal investigations to any extent. The government bureaus, notably the Biological Survey and the Forest Service, are apparently doing more, at present, than any other agencies, but their work is incomplete.

This lack of attention to zooecology, or perhaps better, bioecology, is the more to be deplored because the problems of culture, maintenance and administration of agriculture in general and forage and forest in particular so directly involve animals as well as plants. Many questions which arise are essentially biological rather than botanical or zoological alone.

Much of our practice in grazing, forestry and animal administration is still on a basis of trial and error, when it ought to be scientifically grounded. Adequate provision through existing scientific organizations or new ones for the study of plants and animals together would be of extraordinary value both to the advancement of biological science and the welfare of the people.

RADIO TALKS ON SCIENCE[1]

SPONTANEOUS COMBUSTION

By Dr. CHARLES E. MUNROE
NATIONAL RESEARCH COUNCIL

WHEN you light gas it ignites and burns because coal gas is inflammable and combustible and because it comes into contact with and becomes mixed with air, which surrounds the gas burner. Analysis shows that air is a mixture of many gases, the principal ones being oxygen and nitrogen, but the oxygen is the one of them which reacts with the gas to bring about the burning. All ordinary combustion is due to a similar chemical reaction between a combustible substance and oxygen.

It is familiar to all that kindling wood ignites more easily and burns more readily than the logs from which the kindlings have been cut, and that shavings of this same wood ignite still more easily and burn still faster. If we throw the sawdust from such wood into the air so as to produce an intimate mixture of the two, on ignition the combustion will be so rapid that an explosion may result. All finely divided combustibles such as dusts, vapors and gases form dangerous mixtures with air.

The readiness with which substances burn and the fierceness of the fire is the greater the richer the air is in oxygen; and, when pure oxygen is made use of, iron and many other substances usually regarded as incombustible burn readily in contact with it. By the use of oxygen combustion may go on under water. An experiment frequently shown in chemistry lectures is performed by partly filling a conical wine-glass with warm water, dropping into it a bit of phosphorus which will drop to the bottom and melt, and then, by means of a glass tube attached by a rubber tube to a cylinder containing compressed oxygen, leading the oxygen into contact with the phosphorus when the latter will burn brightly under and in contact with the water.

In lighting gas or the paper or shavings used in starting a fire, the match is used to heat them up to the temperature at which they will react with the oxygen in the air in which they are immersed. To produce fires it is necessary to have present a combustible, a

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of Mr. W. E. Tisdale.

supporter of combustion, such as oxygen is, in contact with it, and that they shall be heated up to the temperature at which the action begins. Each is equally essential.

There are many ways in which bodies may be heated besides by a burning body, such as a match. Friction supplies one way, and long before matches were invented our ancestors started a fire by the friction of two sticks twisted against one another. Later, they ignited gunpowder in a flint-lock musket by the friction of flint on steel, which struck a spark. More than a century ago Dobereiner demonstrated that when gases came in contact with porous solids the gases were condensed within the solids and heat produced to such an extent that if the gas was a mixture of combustible gas and air or the solid was combustible and the gas air, the combustible took fire and burned. Fermentation, due to bacterial action, also causes bodies in which it is taking place to heat up. There are still other natural agencies continually operating which may cause combustible bodies in contact with air to heat up to the temperature at which they take fire and burn. It is fires originating under such conditions that are designated as having been caused by spontaneous combustion.

It is well known that fires are of frequent occurrence in paint shops, and until recent times they were looked upon as of mysterious and perhaps supernatural origin, as they broke out when no one was about and under circumstances which did not warrant suspicion of their having been deliberately started. The chemist has found the cause to lie in the presence in paint shops of oil and particularly linseed oil which, when exposed to the air, greedily takes up oxygen from it and heats up. This occurs the more readily if this oil drops upon the porous lampblack, also much used by painters, for then, owing to the operation of the Dobereiner effect, the mixture rapidly heats up to its point of ignition and burns.

Other combustibles, such as cotton waste, rags and the like, which contain oil, behave in a similar manner, though they may not ignite so promptly; many a house has been set on fire and destroyed by oily rags or waste on which the painter has wiped his hands, or that has been used in oiling the floor. *Beware of oily rags!* Keep them during the day, when not in actual use, in a tinned can or bucket, and burn them up, in a safe place, at the end of the day's work.

Charcoal, in lumps, is so porous that it may, unless carefully cooled and slowly aerated as it comes out of the kiln or retort in which the wood is charred, absorb and condense air within its pores so fast as to burst into active combustion. Charcoal fires in railway cars, on which it is being transported, or bins in which it was stored

have been numerous. When a steam coil is placed very close to a wooden wall the wood may in time become very dry and porous, and sufficiently so to absorb and condense air within its pores and to break out into flame. Many fires in buildings have started in this way. Make a survey of your heaters.

Though most of us nowadays buy our bread from the bakers, yet pretty nearly everybody has some knowledge of fermentation, which is taking place in nature all about us when the proper conditions of fermentable materials (such as starch, sugar or cellulose) and moisture and temperature exist together. A proper initial temperature to start the reaction is as essential in fermentation as it is in lighting the gas or shavings. When but a moderate amount of moisture is present the heat evolved in fermentation may raise the temperature of the pile to such a degree that the fermenting material takes fire and burns. This has frequently occurred with brewers' grains, castor pumace, new-mown hay and similar organic substances. The cut grass is spread in converting it into hay in part to avoid this fermentation. Many a barn has been burned because, owing often to inclement weather, hay has been stored in the loft before this hay was fully cured.

You have noticed, particularly on dry, cold days in winter, that, as you walked across the rug, when you were wearing carpet slippers, or in your stockinged feet, you acquired on your body an electric charge and that as you touched a radiator, or faucet, a spark was emitted from your finger. Some persons have acquired, in this way, so considerable a static charge as to be able to light the gas by the spark from their finger. Moving belts, driving machinery, and other parts of the mechanism acquire quite considerable static charges and these have often caused serious fires in grain elevators, rubber mills, explosives factories, cereal works and other industrial establishments where inflammable materials and especially dusts and vapors existed. To play safe electrically, ground the machinery and keep the place free from combustible dusts, vapors and gases.

Objects moving through the air, tanks containing an oscillating liquid, such as gasoline, when the tanks are mounted on rubber-tired trucks, cylinders holding compressed gases, when the contents issue through small openings as a mist, all acquire very considerable static charges and the sparks attending the discharge have been the initiating cause of the destruction of many hydrogen-filled dirigibles. The authorities in our army and navy have wisely decided that our dirigibles shall be filled with incombustible helium.

The menace of the static charges on gasoline tank trucks, which led to many fires at filling stations, has been overcome by attaching

to the tank a chain long enough to drag on the earth, thus "grounding" the tank.

Compressed and liquefied oxygen is meeting with larger and larger use in oxy-acetylene and other blow-torches, in explosives and for other purposes; and it is proposed to operate blast furnaces with this element. It is obtained by liquefying air and, through fractional distillation, separating the liquid into its components. Compressed oxygen is put into strong steel cylinders under pressures of 1,800 to 2,000 pounds per square inch. Naturally accurately fitted valves are required to confine the gas and liberate it as wished. There is a temptation to put oil on these valves to make them work more easily, but don't you do so, for through the fire and explosion that may follow you may be destroyed. Because of the many accidents from this cause Professor Hersey and his associates have, for nearly two years, made this matter a subject of experimental investigation at the Bureau of Mines Experiment Station, Pittsburgh, and he published an article entitled "A study of the oxygen-oil explosion hazard" in the *Journal of the American Society of Naval Engineers* for May, last. As you value your life and property, protect them by implicitly following the "practical safety precautions" set forth by Professor Hersey whenever you fill, handle, store, transport or use cylinders containing compressed gases.

GLASS

By H. E. HOWE

INDUSTRIAL AND ENGINEERING CHEMISTRY

It is doubtful whether any of man's inventions mean more to the race than the chemical compound glass. The everyday uses of glass are numerous, both in the home and in every industry. It is indispensable to the scientist who without the microscope and other optical instruments could not have performed his work in adding an average of sixteen years to the life of men within the last two generations. To glass also we owe those aids to vision which are beyond price and those great discoveries impossible without lenses for astronomy and photography.

Glass is a chemical compound of which there are a great many varieties. The differences between some of these are so slight as to require intricate instruments to distinguish them. The various classes of glass are distinct, and it is seldom that glass of one class can be used for the same purpose as that of another. Thus the most excellent plate glass is not satisfactory for optical purposes.

Glass is composed of such compounds as silica or sand, soda ash, potash, lime and the oxides of lead, to name only the more common ones. To impart color to glass, gold is used for ruby, selenium for pale rose, copper for red, silver for yellow, carbon for brown, cobalt for blue, nickel for purple and chromium for green colors. Sulfur gives shades from a greenish yellow to black, depending upon the materials in the glass with which it can combine to produce pigment materials.

Formerly all glass was made by the handblown process, but today much of it is made by machinery, thanks to the contributions of the mechanical engineer, the physicist and the chemist, the latter having so improved the glass composition as to give it the mechanical strength necessary for these operations. The glass blower who formerly worked on short shifts before the furnace, swinging in a pit a heavy charge of glass gathered on his blow pipe from the molten mass, has been replaced by the glass-blowing machine. One type of machine draws up great cylinders of glass directly from the tank furnace and from these cylinders our window glass is made. Another machine gathers the molten glass, molds it into table tumblers, finishes these, anneals them and delivers them to the packing cases at the rate of 20,000 a day. Still another type of machine produces glass tubing or glass rod by pulling the glass under constant speed from the tank furnace, air being used if tubing is the product, while without the air glass rods of practically any length are manufactured.

Bottles, electric lamp bulbs and similar articles of quantity production are now machine blown. Whereas window glass is still made from machine-drawn cylinders, a machine which will produce sheet glass directly from the furnace is being developed. In all this work the invention of the mechanical engineer awaited the results of the chemical laboratory before their perfection.

It is in optical glass that the greatest progress from the standpoint of science has been made in recent years. New discoveries in astronomy, biology, physics and chemistry followed the perfection of new types of optical glass late in the nineteenth century. Prior to 1914 there had been no optical glass and very little chemical glassware made in America. The relatively small market, the difficulty of manufacture, the lower costs abroad, all had contributed to the willingness to purchase these specialties in Europe. A wonderful record in the production of other varieties of glass had been made, and the mechanical development in glass manufacture had been carried further in America than elsewhere. Then the time came suddenly when these particular glasses were all-important for telescopes, field glasses, range finders and other military equipment

requiring the finest optical systems, as well as chemical glassware necessary in the control of industrial processes. America called upon her scientists to develop for her while she waited an optical glass industry such as had been built up during thirty years of European experience.

It is notable that the success which attended these efforts was due largely to information acquired by scientists working in the field of pure research, rather than to those experienced in glass manufacture. Important contributions were made by the Geophysical Laboratory of the Carnegie Institution of Washington, where specialists in the silicates were able to apply their knowledge so as to overcome great difficulties, and by the Bureau of Standards of the Department of Commerce, which contributed invaluable service in developing new types of pots in which the optical glass batch is melted. The Geological Survey performed its part in locating necessary deposits of exceptionally pure sand, special clays and other required raw materials. By correlating available information on the physical characteristics and chemical composition of glasses, it was possible to prepare after one or two trial melts large quantities of glass to the exacting specifications of the mathematical optician. Within a short time America was able to supply her own optical glass and a surplus for her allies.

Concurrently chemical and scientific glassware for laboratory and plant use was developed to a high degree of perfection and continues to be supplied not only for that type of work but for household purposes and more lately as chemical engineering equipment for chemical plants.

For many, the most important glass is that supplied in spectacle lenses. The old practice was to blow large balloons with heavy walls and then cut from the surface a number of rough lenses to be ground and polished. More recently this glass has been made in sheets in much the same fashion as window glass. The oval or round blanks are cut out and pressed roughly to shape before grinding and polishing to accurate curves. This grinding is done with successively finer grades of emery or corundum, and the lens is polished to a brilliant surface with oxides of iron. During the various operations the lenses are held in place by a mixture of pitch and rosin. The edges are ground on carborundum stones, and if cemented as in the old type of bifocal, the gum from the Canadian balsam tree is the favorite cement. The invisible bifocal made by fusing together in the electric furnace two kinds of glass, the curved surfaces of which are previously ground and polished, is a valuable contribution of the last few years. One-piece bifocals, that is, a

single lens with one part focused for reading and one part focused for distant vision, have also been prepared commercially.

The properties of all glass depend upon those of silica and the silicates, borates and phosphates, all chemical compounds which are formed in the production of glass. New characteristics depend upon new compositions. Having learned the requirements, scientists continue in their effort to improve glass, and should they be as successful as were the investigators between 1880 and 1900, there might follow another series of advances in the important sciences which would open up for the benefit of the race a corresponding new series of discoveries and inventions.

MEASUREMENTS OF THE TEMPERATURE OF MARS

By Dr. W. W. COBLENTZ

U. S. BUREAU OF STANDARDS

IN beginning this talk to-night I can not refrain from expressing a feeling of awe and wonderment at the progress made in radio. I wonder how many of you who are listening in realize that the whole subject of wireless telegraphy is but little more than twenty-five years old. In the winter and spring of 1900 a fellow-student, Cartmel, and I transmitted electromagnetic waves from one building to another at Case School of Applied Science, Cleveland, Ohio. The receiving and the sending apparatus was so crude and uncertain in its action that when we were ready to send the wireless waves we first signaled to each other with bicycle lamps. No wonder the local papers came out in large headlines telling how "through a blinding snowstorm" two Case students had sent wireless messages from one building to another.

In the meantime has come all this wonderful development, even to radiotelephony.

Now here I am to-night, using the spoken word, transmitted in electromagnetic waves, across many miles of space, to tell you something about the measurement of the temperature of the planets, especially of Mars.

Whether or not Mars is inhabited and whether or not the Martians attempted to signal to us with bicycle lamps or other means, during the past summer, we do not know. But we do have something definite regarding the temperature of the surface of Mars. Our measurements show that the temperature of the dark areas on

Mars rises above 0° C. This shows that vegetation can exist on Mars. Whether vegetation does exist on Mars is an entirely different question, which depends upon the presence of oxygen.

Mars rotates on its axis once in twenty-four hours and thirty-seven minutes. Hence its day is about one half hour longer than ours. But its seasons are about twice as long as ours. As a result during the long summer season in the polar regions of Mars the temperature rises considerably, just as it does in Alaska and Siberia.

The temperatures of the planets are measured by means of extremely small thermocouples, made of two kinds of wire, the diameter of which is smaller than that of a human hair. The junctures of these two wires are flattened into little disks called receivers, which are about one one hundredth of an inch in diameter. These thermocouples are mounted in the eyepiece of a reflecting telescope. They take the place of the cross-hairs in the eyepiece, and the temperature measurements are made by setting these thermojunctions (instead of the cross-hairs) upon the bright and the dark spots on Mars, also on the craters of the moon. The heat rays emanating from these spots warm the little metal receivers, giving an indication of the temperature of the surface.

You are all familiar with the dark and bright markings on the moon, as viewed without a telescope. These markings have the appearance of the face of the "man in the moon." Similarly, but as viewed through a powerful telescope, the surface of Mars shows bright and dark areas, resembling somewhat the markings on the moon as viewed with the naked eye. Superposed upon these somber markings are the polar caps of Mars, which shine forth as bright as the frosted bulb of an incandescent lamp. But strange to say, these bright polar caps are cold. When the thermocouple receivers are placed upon the image of the polar caps they show no heating because the polar caps do not emit infra-red rays. The polar caps are no doubt composed partly of snow and ice. The observations on the polar caps form some of the most interesting and fascinating parts of the work of measuring the heat radiated from Mars.

It was observed long ago by Schiaparelli and by Sir William Herschel that the polar caps wax and wane, which would be the case if Mars has seasons of winter and summer as we have on this earth.

The radiometric measurements made by Mr. C. O. Lampland and myself at the Lowell Observatory, Flagstaff, Arizona, confirm in a remarkable manner the deductions from the visual observations which have been in progress for years. For example, from the fact

that the glistening white appearance of the equatorial region of Mars is not visible at the Martian noon hours it was concluded that the frost or snow melts and the temperature rises above freezing. Similarly, from the disappearance and reappearance of frost and snow on the bright and the dark areas it was concluded that the bright areas are high plateaus which have a lower temperature than the dark areas.

As viewed with the eye, the dark areas are observed to change in color with changes in the season. In the Martian spring season these areas have much the appearance of the bright areas. As the spring season advances, these dark areas assume a darker appearance and show a more distinct bluish-green color. Later on as the season advances to what corresponds to autumn on this earth the dark markings on Mars take on a more brownish or copperish color. From these changes in configuration and color these dark markings have been interpreted as being caused by the presence of vegetation. Of course you understand that while some astronomers have given this interpretation to their observations others have taken the opposite view and have held to the belief that the temperature of Mars can not rise above the freezing point of water.

Now let us notice the results of our radiometric measurements. Our radiometric measurements show that the bright areas on Mars are cooler than the dark areas. This is just the reverse of conditions on this earth, where the surface of the bare desert areas becomes burning hot. The temperatures of the bright areas on Mars are down to freezing, that is to say, 32° F, while the dark areas have a temperature of 50 to 60° F which is not unlike conditions in New York, Philadelphia or Washington on a bright day in March and April. The radiometric measurements therefore support the conclusions drawn from the visual observations, and make the explanation quite plausible that the bright areas are so cool because they are high plateaus.

By setting the thermocouple receivers on the eastern and the western limbs or edges of Mars we found that the morning or sunrise side of the planet is much cooler than the afternoon or sunset edge of Mars. This is of course similar to conditions on this earth, the main difference being that on Mars the temperature falls to a much lower value at night, when the temperature drops down to — 80° F or perhaps even lower. This is owing to the fact that the atmosphere of Mars is rare, which facilitates cooling of the surface by radiation.

An interesting experience was the observation of the change in temperature of the surface with advance in the summer season on the southern hemisphere of Mars. We all know of the intense cold

in Alaska and Siberia, during the winter, followed by a short warm summer. Similarly, our measurements on the polar caps of Mars indicated temperatures down to —90° F. in winter. But in the summer season, when the south polar cap had quite disappeared, the temperature was up to 50° F.

An interesting result of our radiometric measurements is the high temperatures observed on the dark areas on Mars. These temperatures are up to 50 to 60° F., which is equivalent to a warm spring or autumn day. As already stated, to the eye these dark areas have the appearance of vegetation. But this vegetation is probably quite unlike the plant life with which we are most familiar. It must be of a type that will withstand extremely dry weather and intense cold. Mars has but little water. Hence it is evident that what little vegetation may be present on Mars must be adapted to a dry climate.

Although the intensity of the sun's rays falling upon Mars is only about one half as great as falls upon the earth, the surface of Mars absorbs and utilizes about 85 per cent. as much of the total incident solar radiation as does the earth. Hence it seems evident that the temperature of the surface of Mars should rise almost as high as that of the earth.

The observed high local temperatures on Mars can be explained best by the presence of vegetation which grows in the form of tussocks or thick tufts, such as the pampas grasses, and the mosses and lichens which grow in the dry tundras of Siberia. The upper surface of such vegetation has a high absorption for sunlight, while the part beneath has a low heat conductivity. Hence from the very nature of the growth, namely, in tufts, but little heat is conducted to the ground, which may be frozen. For example, travelers in Siberia have found that the temperature of the top layers of the tundra mosses may be up to 75° F., while the ground only an inch or two underneath was frozen.

I think that the assumption of the presence of vegetation growing in tussocks is a reasonable explanation of the observed high temperatures on Mars; and it is in harmony with the visual observations which show changes in the dark areas with changes in the seasons. But the term high temperature is merely relative. With noonday temperatures of only 40 to 60° C. even on the hottest spots on the equator and with exceedingly low temperatures at night it seems evident that any vegetable or animal life that may exist on Mars must be adapted to withstand great extremes in temperature and humidity. From the way animals and plants adapt themselves to conditions on our deserts it seems possible for life to adapt itself to conditions on Mars.

Part of this adaptation would consist in being inactive over much longer periods than occur on this earth. Animal life would have to be troglodytic, able to burrow deep and hibernate or able to migrate or able to withstand the intense cold in a benumbed state as do, for example, the torpid grasshoppers, wasps and ants which one finds on warm days in winter. Life on Mars can not be very pleasant, especially in the equatorial region where it would be a continuous process of thawing out and limbering up in the forenoon and a reversal of the process in the afternoon. In the Martian polar regions, where the summer day is almost six months long, temperature variations would not be so extreme, and living matter, if present, would not be subjected to such short periodic changes in activity as occur on the equator. The cycle of reproduction and development of the living cell would not be subjected to such extreme temperature conditions. Similarly, the quiescent period during the prolonged winter would be free from interruptions.

Thus ends my story of temperature conditions on Mars. It was my good fortune to be the first to measure the temperature of Mars. "Sic volvere parcas"—thus spin the fates.

HOW MOUNTAINS ARE MADE

By Dr. WM. BOWIE

U. S. COAST AND GEODETIC SURVEY

THE earth is a solid globe, 8,000 miles in diameter. It has no liquid interior with volcanoes as chimneys. It is subjected to great strains as a result of the erosion of materials from the land and their piling up at the mouths of rivers. Earthquakes occur daily, though most of them can only be detected by the seismograph, one of the most sensitive instruments of the world. When an earthquake occurs, the land is moved only a few inches or feet, showing the rocks are after all not very strong. The earth is not going to blow up, nor will it collapse under our feet. But in the millions of years to come some parts of the land areas will be in the oceans, and some portions of the oceans will be added to continents or may be changed to islands. These things have occurred in the past and they will continue during the ages to come. There is no such thing as an everlasting hill.

Every continent has mountains, which not only add to the grandeur of the landscape but are of great importance to us in our daily lives. Irrigation projects in arid regions and hydroelectric

power plants are dependent upon the mountain streams and rivers. Without the mountains, which make the winds pay tribute in the form of rain, some parts of our area would indeed be deserts.

We should not consider mountain areas as great wastes, nor should we think of the great ocean areas as being of no importance except for fishing and the navigation of ships. If it were not for the oceans there would be no rain and without rain how would food be obtained?

The mountains have been mysteries from the time human beings began asking "why." Many explanations have been made as to their origin, but it is only in recent years, and as a result of researches principally by the United States Coast and Geodetic Survey, that we are able to advance a satisfactory explanation.

It has been found that the earth has a crust of rock resting on denser materials, which, though rigid to forces acting for short periods of time, will yield like putty or sealing wax when the forces act for tens, hundreds or thousands of years. The crust therefore floats, just as logs will float on a mud flat.

The reason we have continents and islands standing up above the oceans is because the crustal material under the ocean is denser than that under the land.

A chestnut log will stand out of the water higher than an oak log of the same size, because it is not so dense. For the same reason the lighter crust under continents stands up higher than the denser crust under the oceans.

Except for a thin layer of soil composed of sand, clay and loam the earth is made up of rock. The outer rock is mostly sandstone, limestone and shales, all of which were formed from materials washed down from the land and later compacted and cemented. Lower down are granite and basalt not formed from sediments.

Probably no rock seen at the surface came from a depth greater than twenty-five miles. No one knows what kinds of rock exist at lower depths. They may be ores, containing iron, lead or copper or even the precious metals. We know that the average density of the earth is about twice as great as that of the rocks at the surface. We do not know whether the greater density of the interior rocks is due to the presence of metals or to compression by the great weight of the outer rocks.

The mountain is a late comer on the earth. Rain has only been falling for about a billion and a half years, and before the rain fell there was nothing to disturb the face of the earth.

Each mountain system existing to-day is occupying a part of the earth's surface, which was earlier a part of an ocean or a great

inland sea. The distorted stratified rocks which can be seen in any mountain region are formed from sand and mud, carried by rivers and laid down in large bodies of water. Most of these rocks contain fossils of marine plants and animals. The mountains were formed along the margins of water into which the rivers and streams dumped the materials which were washed away by the rains. The sediments were accumulated in vast beds having thicknesses as great as six miles.

The weight of these sediments covering thousands of square miles, in rather thin strips along the margins of the oceans and seas, was tremendous. This load disturbed the crust floating placidly on the softer interior material. The crust beneath the sediments was forced down into hotter regions where it took up the greater temperature. This made the crust expand as a result of chemical or physical processes and a mountain system was formed.

The most delicate and accurate measurements by the U. S. Coast and Geodetic Survey and geodetic organizations of other countries show that the earth's crust everywhere is in equilibrium, just as an ice field on a quiet ocean is in equilibrium. Unless there is melting of the ice or there are winds and currents disturbing it there will be no ice ridges formed nor will any block be forced up or down.

Since the earth's crust is now in equilibrium, it must have been so in the past. Therefore when a large part of the crust changed the elevation of its surface from one to five miles there must have been a change in its density.

Before the rain first began to fall, about a billion and a half years ago, there were no mountains, but the earth's surface was not smooth like a ball. There were broad hollows and wide high areas. We know this as the result of researches by Dr. Henry Washington, of the Geophysical Laboratory of the Carnegie Institution of Washington. He discovered that the lava rocks found on the islands of the oceans have the heavier chemical elements present in larger percentages than the lava rocks found on the continents. Therefore, the rocks under the oceans are heavier than those under the continents, and the crust under the oceans is not so thick as under the land.

This condition existed when the rain began to fall. The water collected in the hollows, forming the oceans and seas, and the high land stood out as continents and islands.

Why the rocks in some parts of the crust should be heavier than in others no one knows. This is a problem some scientific investigators are working on, but it may never be solved.

We may infer that the earth's surface was too hot for water to remain on it before the sedimentary rocks began to be formed. Previously, the water must have existed as vapor or steam.

How long the earth has existed as a solid mass no one can guess, but it must have been several billions of years.

How long will it support life? We do not know. But if its surface temperature was 212° F., or the boiling point of water, one and a half billions of years ago, and is now about 50° as an average, it will be many millions of years before it will be too cold for life to exist. We need not worry about what takes place after that.

Some great force must have been at work to lift up great rocky masses like the Himalayan and Andes mountains, with peaks four or five miles above sea level. A single cubic mile of rock weighs twelve billion of tons, while a mountain system has thousands of cubic miles of rock which were once below sea level.

The earthquakes, occurring daily with only slight changes in elevation of the surface of the earth, show that great forces do not accumulate to shove up a mountain as a break in the crust all at once. If this should occur the earth would be shaken so hard that great waves from the oceans would roll right over the continents and drown all land animals. This would have occurred with the formation of each mountain system. A century ago scientists believed this was the way in which mountains were formed, but no one does now.

After considering all the geologic and geodetic data we are forced to the conclusion that the shifting of material over the earth's surface by rain water running from the land to the oceans and seas, carrying great masses of sand and mud and depositing them along the coasts, is the real cause of mountains. Each little muddy stream is doing its bit, and each big river, like the Mississippi, the Amazon and the Nile, is doing its big bit, to make new mountains which we expect to appear in a future geological age—possibly several hundred millions of years from now.

While new mountains will be formed where great beds of sediments are accumulating, the existing mountains will be worn down. The United States is losing six hundred cubic miles of material each ten thousand years. The mountains are gradually disappearing. Under the mountains the crust is being buoyed up with the wearing away of its surface. The crustal materials are coming into cooler regions. The result of this is that after the mountains disappear the crust below will contract from the loss of heat. Where we now have mountains there will be low ground or there may be seas or parts of the oceans into which new sediments will be dumped.

Some areas now occupied by mountains have been above and below sea level several times.

There has been plenty of rain to cause all the mountains of the earth. The average rainfall now is thirty inches each year. This means a mile of rain in two thousand years. If the rainfall has been the same during the sedimentary age of one and one half billions of years nearly a million miles of rain has fallen.

Of course, the same water has been used over and over again, for if all the water were spread out evenly over the earth its depth would be slightly less than two miles.

From all the available evidence we must conclude that rain, due to repeated evaporation and precipitation, has caused the wearing away of the soil and the laying down of great masses of sediments along the margins of oceans and seas and has produced the great changes in the elevation of the earth's surface.

Earthquakes and volcanoes and the formation of minerals, oil and coal are merely incidents in the general process. We have earthquakes as the sediments depress the crust, as the crust below them swells up to form mountains, as the crust is buoyed up under the areas undergoing rapid wearing away, and as the crust cools and sinks under worn-down mountain areas.

Volcanoes and lava outflows are probably caused by the cracking or rifting of the crust in areas where mountains and islands are in the process of formation. The cracks must extend deep enough to reach rock that is very hot but solid under the great load of the outer rock. With the cracking of the crust the deep rock becomes soft and flows to the surface.

Don't be afraid of old mother earth. As I said before she is not going to collapse nor is she going to blow up. She will adjust herself to strains once in a while, and the earthquake will tell you when she does. If we should keep away from the ocean shores and should live in tents she would not hurt us. Few would get hurt if we knew where earthquakes are likely to occur and if we guarded against them by erecting earthquake-proof buildings. We shall build better in the future after we have made earthquake surveys. It is expected such surveys will be commenced in this country in the near future.

THE PHYSIOLOGICAL BASIS OF ATHLETIC RECORDS[1]

By Professor A. V. HILL, F.R.S.
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In the study of the physiology of muscular exercise there is a vast store of accurate information, hitherto almost unexploited, in the records of athletic sports and racing. The greatest efforts and the most intense care have been expended in making what are really experiments upon these subjects, and the results obtained represent what may justly be described as a collection of natural constants of muscular effort in the human race. It is the purpose of this address to discuss certain aspects of the data available in connection with various forms of racing, and to see how far physiological principles at present known underlie them.

Sources of Information

The most complete set of records available, for a great variety of sports, is to be found in "The World's Almanac and Book of Facts," published by the New York *World*. Much of the information here presented was obtained from the 1925 edition of that work; similar but less extensive data can be found in our own Whitaker's Almanack. In addition, various books on horse-racing, on swimming and on rowing have been searched for suitable material. The study of such data is not new. In most cases, however, it has been carried out not from the physiological but purely from the statistical standpoint; insufficient knowledge of the underlying physiological principles was available to make it profitable to ask for the why and wherefore. Recent developments, however, of the scientific study of muscular effort in man have indicated certain broad lines on which some at any rate of the relations so established can be explained. I will not deal further with the statistical analysis of the facts, beyond referring to an extremely interesting and suggestive collection of them given in a paper by A. E. Kennelly, entitled "An approximate law of fatigue in the speed of racing animals," published in the *Proceedings of the American Academy of Arts and Sciences*, vol. xlii., p. 275, 1906. Some, indeed, of my data are taken directly from that paper.

[1] Address of the president of the Section of Physiology of the British Association for the Advancement of Science, Southampton, 1925.

Fatigue as the Determining Factor

An important and interesting problem for any young athlete is presented by the question, "How fast can I run some given distance?" The maximum speed at which a given distance can be covered is known to vary largely with the distance. What are the factors determining the variation of speed with distance? How far, knowing a man's best times at two distances, can one interpolate between them for an intermediate distance, or extrapolate for a distance greater or less? Obviously the answer to such questions depends upon the factor which in general terms we designate fatigue. Fatigue, however, is a very indefinite and inexact expression; it is necessary to define it quantitatively before we can employ it in a quantitative discussion such as this. There are many varieties of fatigue, but of these only a few concern us now. There is that which results in a short time from extremely violent effort: this type is fairly well understood; there is the fatigue, which may be called exhaustion, which overcomes the body when an effort of more moderate intensity is continued for a long time. Both of these may be defined as muscular. Then there is the kind which we may describe as due to wear-and-tear of the body as a whole, to blisters, soreness, stiffness, nervous exhaustion, metabolic changes and disturbances, sleeplessness, and similar factors, which may affect an individual long before his muscular system has given out. Of these three forms of fatigue the first one only is as yet susceptible of exact measurement and description. The second type may quite possibly come within the range of experiment at no distant date. The third type is still so indefinite and complex that one can not hope at present to define it accurately and to measure it. Undoubtedly, however, all these types of what we call "fatigue" influence—indeed, determine—the results which are to be presented.

Presentation of Data

The data will be exposed throughout this discussion in graphical form, and in every case but one (Fig. 5) the quantities plotted are the speed as ordinate and the time, or some function of the time, as abscissa. The reason for taking the *time* occupied in a race as one of our variables is simple; the problem before us, physiologically speaking, is, clearly, *how long can a given effort be maintained?* The length of time is given by the abscissa as the independent variable; the magnitude of the effort, or some function of it, as represented by the speed (that is, by the average speed over the race considered), is given as ordinate. It will be shown below, as Kennelly indicated in his paper, that the ideal way to run a race,

possibly not from the point of view of winning it, but certainly from that of breaking the record for the distance, is to run it at constant speed. In those performances which have attained to the dignity of a world's record it is unlikely that this criterion has been to any very large degree neglected. Apart, therefore, from the fact that there is no speed of which we have any record except the average speed, we are probably not far wrong in using the average speed as a fairly exact measure, or at any rate as a function of the effort involved.

In one case only (Fig. 6) the time occupied in the race has been given on a logarithmic scale: no great virtue attaches to the logarithm, but if 75 yards and 100 miles are to be shown on the same diagram in a readable form it is necessary somehow to condense the abscissae at the longer times. As a matter of fact, from the standpoint of an athlete, one second in ten has the same importance as ten seconds in a hundred, as a hundred seconds in a thousand; in this sense, therefore, a logarithmic scale of time most truly represents the duration of an effort. Such a scale, however, has not been used for any ulterior reason, but only, as in Fig. 6, to get all the available data on to one diagram.

Running and Swimming: Shorter Times

In Fig. 1 all the important world's records are presented, average speed against time, for men and women running and for men

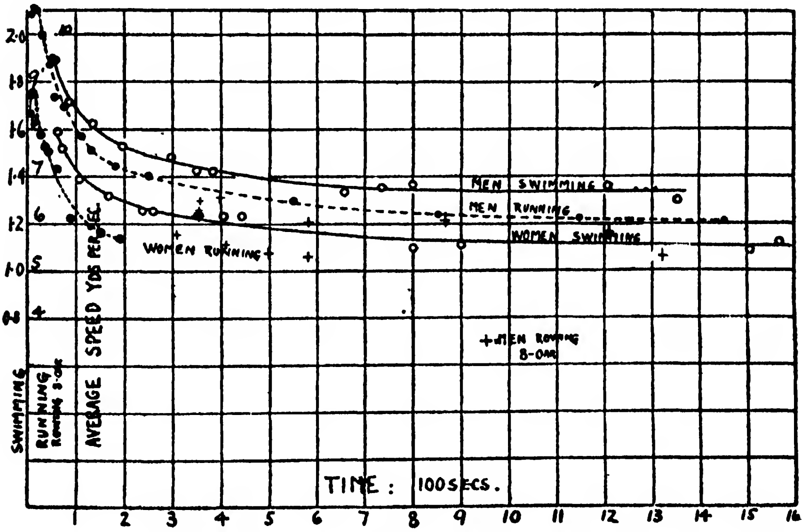


FIG. 1.—World's records for men and women swimming and running: average speed in yards per second against time in seconds. *Note.*—The scale for swimming is five times as great as for running. The observations for men rowing an eight-oar boat are on the same scale as running and are referred to later in the text.

and women swimming. The crosses representing men rowing in an 8-oar boat will be discussed later. It is obvious in all four cases that we are dealing with the same phenomena, a very high speed maintainable for short times, a speed rapidly decreasing as the time is increased and attaining practically a constant value after about 12 minutes. There are no reliable records, in the case of swimming, for times of less than about 50 seconds, so that the curves can not be continued back as far as those for running. There can, however, be no doubt that the curves for running and swimming are essentially similar to one another and must depend upon the same factors. In running, starting inertia is the cause of the initial upward trend of the curves: a maximum average velocity is attained in the case of men for about 200 yards, of women for about 100 yards; after that a rapid decrease sets in, ending only when the time has become 10 or 15 minutes, the distance two to three miles. The phenomena shown in Fig. 1 are susceptible of a fairly exact discussion.

Oxygen Intake, Oxygen Requirement and Oxygen Debt

In recent papers my colleagues and I have tried to emphasize the importance of a clear distinction between the oxygen intake and the oxygen requirement of any given type and speed of muscular effort. When exercise commences, the oxygen intake rises from a low value characteristic of rest to a high value characteristic of the effort undertaken. This rise occupies a period of about two minutes; it is nearly complete in 90 seconds. The oxygen used by the body is a measure of the amount of energy expended: one liter of oxygen consumed means about five calories of energy liberated, enough to warm 5 liters of water one degree Centigrade—expressed in mechanical energy, enough to raise about one ton seven feet into the air. It has been established, however, that the oxygen need not necessarily be used during the exertion itself. The muscles have a mechanism, depending upon the formation of lactic acid in them, by which a large amount of the oxidation may be put off to a time after the exercise has ended. The recovery process, so called, is a sign of this delayed oxidation: it is just as important to the muscle as recharging to an electric accumulator. The degree, however, to which the body is able to run into debt for oxygen, to carry on not on present but on future supplies, is limited. When an oxygen debt of about 15 liters has been incurred the body becomes incapable of further effort: it is completely fatigued. In anything but the shortest races our record-breaking athlete should finish with something near a maximum oxygen debt, otherwise he has not employed all his available power, he has not done himself full justice. The maximum effort, therefore, which he can exert over a given interval

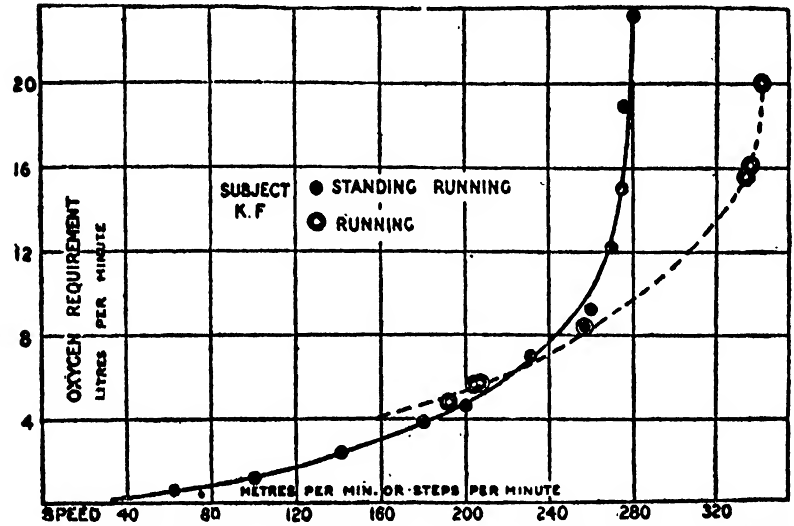


FIG. 2.—Observations of oxygen requirement of K.F. running and standing-running at various speeds. Horizontally, speed: running, meters per minute; standing-running, steps per minute. Vertically, oxygen requirement per minute, liters.

depends upon the amount of energy available for him, upon (*a*) his maximum oxygen intake (that is, his income) and (*b*) his maximum oxygen debt (that is, the degree to which he is able to overdraw his account). These maxima are fairly well established for the case of athletic men of average size—about 4 liters per minute for the one, about 15 liters for the other.

It is possible for a man to make an effort far in excess of any contemporary supply of oxygen. This effort will require oxygen afterwards, and the total oxygen needed per minute to maintain the exercise can be measured. It is what we call the "oxygen requirement" characteristic of the effort involved. Now experiments have shown (see Fig. 2) that the oxygen requirement varies very largely with the speed: it increases far more rapidly than the speed, more like the second or third power of the speed, so that high speeds and intense efforts are very wasteful. These facts enable us approximately to deduce the general form of Fig. 1.

Imagine an athlete with a maximum oxygen intake of 4 liters per minute,[2] capable of running until his maximum oxygen debt has been incurred of 15 liters. If he runs for 15 minutes the total oxygen available during the exercise and in arrears is $15 \times 4 + 15 = 75$ liters: an effort can be made requiring 5 liters of oxygen per

[2] Assumed, for the sake of simplicity in calculation, to commence as soon as the race begins. For a more accurate calculation the gradual rise of the oxygen intake at the beginning of exercise can be taken into account.

minute. Imagine, however, that he exhausts himself not in 15 but in 5 minutes: the total oxygen available during or in arrears is $5 \times 4 + 15 = 35$ liters. He may exert himself more violently, therefore, with an effort equivalent now to 7 liters per minute. Imagine next that he runs himself to exhaustion in 2 minutes: $4 \times 2 + 15$, *i.e.*, 23 liters of oxygen, are available, 11.5 per minute; a correspondingly greater effort can be made. By such calculations it is possible from Fig. 1 to deduce a relation between oxygen requirement and speed. Taking the case of a man swimming, the result is shown in Fig. 3 on the assumption of a maximum oxygen debt of 15 liters, a maximum oxygen intake of 3.5 liters per minute, and the supposition that at the end of the race the performer is completely exhausted. A similar calculated curve is given for the case of running, on the hypothesis of a maximum oxygen debt of 15 liters and a maximum oxygen intake of 4 liters per minute. These curves are similar in character to those shown in Fig. 2 for the cases of running and standing-running, which have been investigated in the laboratory. There can be little doubt that the factors here described are the chief agents in determining the form of the curves given in Fig. 1.

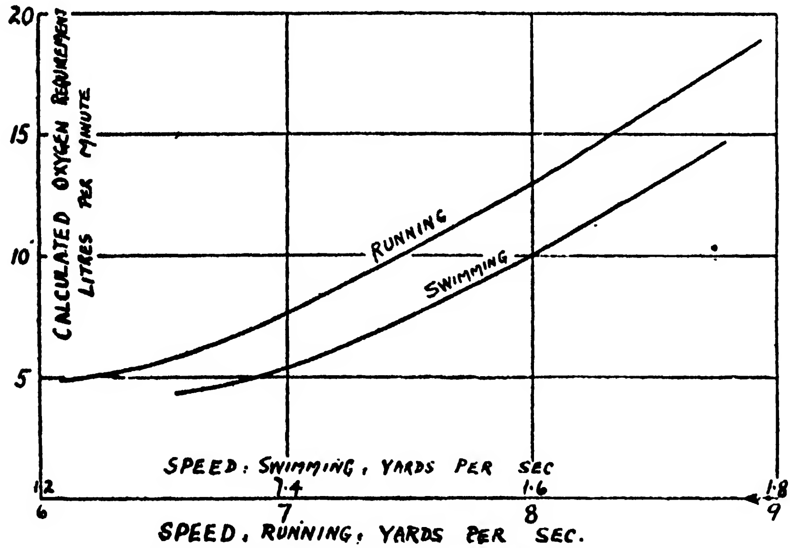


FIG. 3.—Oxygen requirement, running and swimming, of record-breaking athletes, calculated from curves of Fig. 1, on the assumption that at the end of a race the performer is completely exhausted, having attained his maximum oxygen debt. Maximum oxygen debt assumed = 15 liters for both. Maximum oxygen intake assumed: for running = 4 liters per minute; swimming = 3.5 liters per minute. Method of calculation described in the text.

Limits of the Argument

It is obvious that we must not pursue the argument too far. A man can not exhaust himself completely in a 100 or a 200 yards race: even 300 yards is not sufficient to cause an extreme degree of exhaustion, though a quarter-mile, in the case of a first-class sprinter, is enough, or almost enough, to produce complete inability to make any immediate further effort. We have found an oxygen debt of 10 liters even after a quarter-mile in 55 seconds. It is obvious, therefore, that we can not pursue our argument below times of about 50 seconds, that the maximum speed is limited by quite other factors than the amount of energy available. It is not possible in any way to release energy explosively for very short intervals of effort: other factors determine the maximum speed, factors mechanical and nervous. Neither can the argument be applied to very long races, where—as we shall see below—other types of exhaustion set in.

Comparison of Men and Women; Swimming and Running

There are certain characteristics of these curves which are of interest. In the first place those for men and women are almost precisely similar. For a given time of swimming the maximum speed for a woman appears throughout the curves to be almost exactly 84 to 85 per cent. of that for a man. The curve relating oxygen requirement to speed, in the case of swimming, is not known from experiment, nor are the maximum oxygen debts and the maximum oxygen intakes known for women with any certainty. It would be very interesting to determine them, were volunteers forthcoming. If we asume what is roughly true, that the energy expenditure rises approximately as the square of the speed, we may conclude that a woman swimming is able to exert, per kilogram of body weight, about 72 per cent. of the power expended by a man. Women are well adapted to swimming: their skill in swimming is presumably just as great as that of men; the difference in the maximum speed for any given time can be a matter only of the amount of power available.

In running, the same type of comparison may be made, though here not over the same range of times. For anything but the shortest races the maximum speed of a woman is almost precisely 79 per cent. of that of a man running for the same time. For very short times, 5 to 10 seconds, the ratio is greater, namely, 84 per cent. Here again there would seem little reason to attribute the difference of speed, at any rate for the longer races, to anything but a difference in the maximum amount of power expendible

over the period in question. Assuming again, as an approximate means of calculation, that the energy used per minute varies as the square of the speed, we see that a woman running is able to liberate in a given time only about 62 per cent. of the energy expendible by a man of the same weight. It is probable that this ratio between men and women, as determined by swimming and by running, respectively, is really the same in either case, and that the apparent difference depends upon an inexactness in the simple laws we have assumed for the variation of energy expended with speed. It would seem fair to take the mean of these two values, 67 per cent.—that is, about two thirds—as the ratio of the amount of energy expendible by a woman in a given time as compared with that by a man of the same weight. It would be of great interest—and quite simple—to test this deduction by direct experiment on women athletes.

Men and Women Jumping

A further interesting comparison between men and women may be found in the records of high jumps and long jumps. The world's record long jump for a man is 25.5 ft., for a woman 16.9 ft. The high jump records are respectively 6.61 ft. and 5 ft. At first sight, when compared with running, these records for women seem extraordinarily poor: the high jump is only 75.5 per cent., the long jump only 66 per cent., of that for men. Such a conclusion, however, rests upon a misunderstanding, almost like that which makes many people believe that if a man could jump as well as a flea he could easily clear the top of St. Paul's Cathedral. It is a matter only of elementary mechanics to show, on the assumption that a woman can project herself vertically with a velocity proportional to that with which she can project herself horizontally, the constant of the proportion being the same as for the case of a man, that both the high jump and the long jump in the two sexes should be in the ratio *not of the velocities but of the squares of the velocities*. The maximum range and the maximum height of a projectile vary as the square of the velocity of projection. Thus it is right to compare, for men and women, not the height of the high jump or the distance of the long jump, but the square roots of these quantities, if we wish to study their relative performance in jumping as compared with running. This being so, we find that the high jump of a woman, as measured by its square root, is 87 per cent. of that of a man[3]; the long jump, measured in a similar

[3] It would really be fairer to compare the heights jumped, less the initial heights of the centers of gravity, say 3.1 feet and 2.8 feet, respectively. This gives 2.2/3.51 = .63 as the ratio of the heights, of which the square root is .79, a close agreement with the long jump.

way, is 81.5 per cent. These compare closely with their relative performances for very short times of running, where a woman, as shown above, can run 84 per cent. as fast as a man. It is amusing to find simple mechanics explaining such apparent differences between the sexes.

The Characteristic Oxygen-Requirement-Speed Curve

The curves given in Fig. 2 define the economy with which movements are carried out. By such means can be shown the amount of energy required, in terms of oxygen used, in order, say, to run or swim for a minute at any given speed. The curves will vary largely from one individual to another. Some men move more efficiently than others at all speeds: A may be more efficient at one speed than B is, but less efficient at another. For most kinds of muscular exercise the characteristic curve of Fig. 2 is ascertainable by experiment. In some cases, as in swimming, experimental difficulties might be considerable, at any rate at higher speeds. It is obvious, however, that such a curve must exist for any person performing any kind of continuous muscular exercise. In it we have a characteristic of that given individual for that particular form of work.

Skill

Some people are much more skilled than others. To a large degree, of course, the skill and grace associated with athletic prowess is natural and inborn; to a large degree, however, it can be produced by training and breeding. All the movements required in the violent forms of muscular exertion here discussed are rapid ones, far too rapid to be directly and continuously subject to the conscious intelligence: they are largely, indeed mainly, reflex, set going by the will but maintained by the interplay of proprioceptive nervous system and motor apparatus. The nature of muscular skill can not be discussed here; possibly, however, above all other factors it is the foundation of athletic prowess. Such skill has a physiological basis as it has a psychological aspect. It is a fit subject for discussion alike by physiologists, psychologists, students of physical training, athletes, masters and workmen. The further study of skill is likely to be most fruitful in many branches of human endeavor. Here I would only remark that the forms of the characteristic curves of Fig. 2 depend upon the skill of the subject in ordering his movements, just as the "miles per gallon" of a motor-car depends upon the skill of those who designed and adjusted its timing gear and its magneto. Given incorrect adjustment due to lack of skill, given imperfect timing of

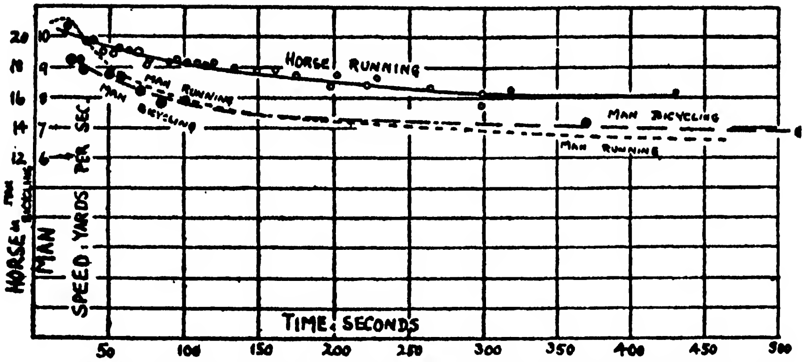


FIG. 4.—Records for horse running and man bicycling; dotted curve for comparison, man running, taken from Fig. 1. Horizontally, time in seconds; vertically, average speed yards per second. *Note.*—The horse, and the man bicycling are shown on half the scale of the man running. The records for bicycling are the unpaced professional records against time. The records for horses were made in America.

the several parts of the mechanism, given unnecessary movement and vibration, the whole system will be inefficient. Fundamentally the teaching of athletics for anything but the shortest distances consists in training the performer to lower the level of his characteristic curve, to carry out the same movements at a given speed for a smaller expenditure of energy.

Bicycling and Horse-Running

Not all forms of muscular exertion are so violent, involve so great an expenditure of energy, when carried out at the highest speed, as running and swimming. In Fig. 4 are two examples of this fact, horse-running and bicycling. For horse-running a long succession of records on American horses are plotted on the topmost curve: below are the records of men bicycling, the unpaced professional records, made not in a race but against time. Most bicycle races are useless for our purpose: the competitors proceed in groups, trying one to ride behind the other to avoid wind resistance, and the speed may be absurdly low. Paced records are of little value because the efficiency of the wind-screen provided by the pacing apparatus is not standardized. These professional records, however, made unpaced, simply with the intention of breaking the record, are probably reliable, and they form a reasonably smooth curve. Plotted on the same diagram for comparison is a curve to represent a man running, a replica of that of Fig. 1. The first two curves are on twice the scale of the third, since a running horse and a bicycling man can go about twice the speed of a run-

ning man. It is obvious at once that neither of these two curves falls anything like so rapidly as does that of a running man; fatigue does not so soon set in: the amount of energy expended at the highest speed must be much less than in a running man. This conclusion, indeed, is obvious to any one who has tried to ride a bicycle fast. It is impossible to exhaust oneself rapidly on a bicycle: the movements are too slow, they involve too little of the musculature of the body; it would require some minutes to produce by bicycling a state of exhaustion easily attainable within a minute by running. The curve for horse-running is almost parallel to that for bicycling; presumably, therefore, the movements of a horse are so arranged that the extreme violence of effort possible in a human "sprinter" is unattainable: possibly the movements are too infrequent, or the qualities of the horse's muscles are so different, that the kind of fatigue rapidly attainable in man is not possible in the horse; possibly the horse will not "run himself out" so completely as a man.

Bicycle Ergometers

The curves of Fig. 4 are of interest in connection with the numberless experiments which have been made with bicycle ergometers. Nearly all the laboratory observations on man, in connection with muscular exercise, have been made with that implement. It has been obvious to my colleagues and myself during the last few years that the types of exercise chiefly adopted by us, running and standing-running, are more exhausting and require a far greater expenditure of energy than those employing the bicycle ergometer. In rowing and in pedalling a bicycle it may not be possible to attain respiratory quotients of 2 or more during or shortly after exercise. After running, or standing-running, however, very high values are attained, due to the fact that these latter forms of exercise, at the highest speeds, are so very much more energetic than the slower movements of rowing or bicycling. It is speed and frequency of movement which determine the degree of exhaustion produced by it. To exert a powerful force in a moderate rhythm is not anything like so tiring as to exert a much smaller force in a frequent rhythm: hence the reason for "gearing up," as in the bicycle and in the long oars of a rowing-boat.

Horse-racing

The fact that running is not so exhausting to a horse as to a man is well shown by the records of Fig. 5. There the small circles represent the best English records of horse-racing between the

years 1721 and 1832. Speed in meters per second is given against kilometers distance. The larger circles represent the best of some more recent English records, from 1880 to 1905. D, O and L represent respectively the Derby, the Oaks and the St. Leger. It will be seen how little the speed falls off for the longer races: six or seven kilometers are run at the same speed as one or two. There is, indeed, a visible tendency for the curve to rise towards the left, as in Fig. 4; there is, however, no obvious further fall of the curve towards the right after about two kilometers. Such a statement would seem preposterous to a human runner if applied to himself. Either the horse can not exhaust himself so rapidly as a man, or he can not be induced by his rider to go as hard as he ought. A man may be able to force himself to a greater degree of exhaustion than his rider can force a horse. An amusing incidental point brought out by Fig. 5 is the fact that the small circles and the large ones are intermingled. The horses of 150 years ago could run just as fast as their modern successors—a fair comment on the doctrine that the improvement of the breed of horses is the chief and a sufficient reason for encouraging the continuance of horse-racing—even in time of war.

The Logarithmic Graph

Let us pass now to a consideration of the last diagram, Fig. 6. There average speed in a race is plotted against the logarithm of the time occupied in it, the logarithm being employed, as stated

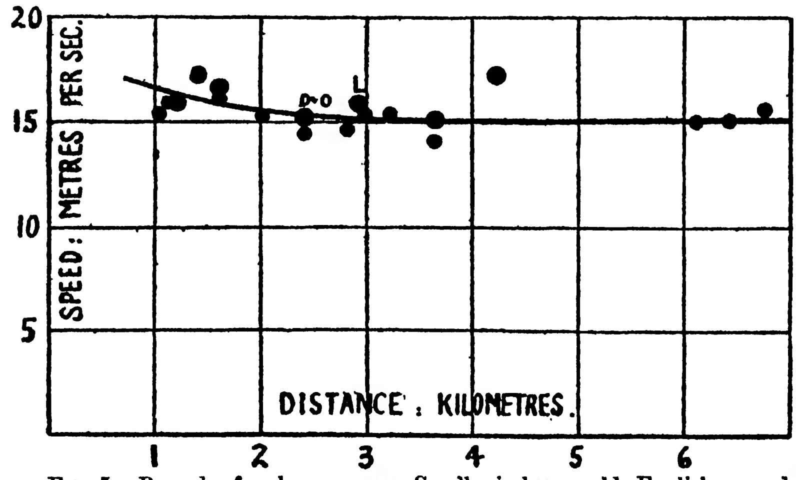


Fig. 5.—Records for horse-races. Small circles = old English records, 1721–1832. Large circles = later English records, 1880–1905. D = Derby, O = Oaks, L = St. Leger. Average speed, meters per second, against distance in kilometers.

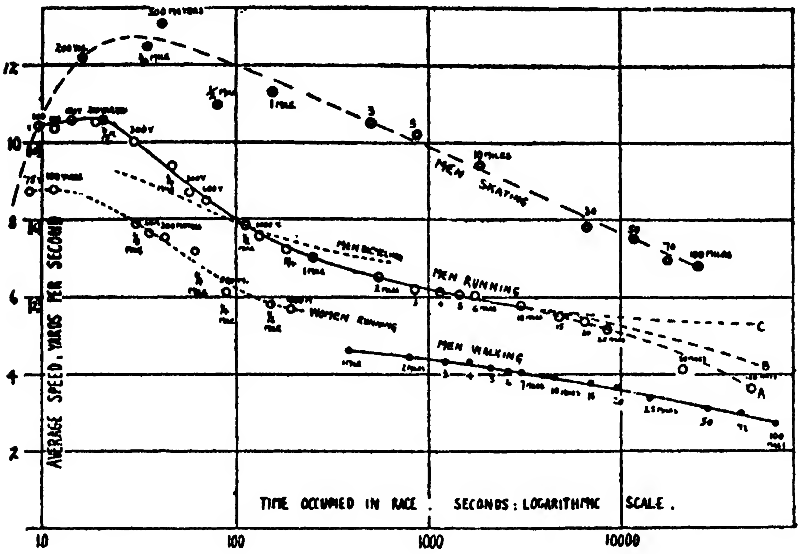


FIG. 6.—Records for men skating, bicycling, running and walking, and for women running. Horizontally, logarithm of time occupied in race; vertically, average speed in yards per second. The same scale is used throughout, except for bicycling, where half the scale is employed, as shown in square brackets. The curve for men running appears to be somewhat doubtful beyond 10 or 15 miles, and three alternative curves are shown by broken lines.

above, for the purpose of including all records from 75 yards to 100 miles in the same picture. That people think, to some degree, in logarithms, although unconsciously, is shown by the fact that the records which men have thought it worth while to make are distributed approximately uniformly over the picture from left to right. Fig. 6 presents the data of athletics perhaps more clearly than any other. The initial rise of the curve for men running, which is due to starting inertia, is very obvious. The rapid fall beyond 220 yards is clearly seen. It is obvious that the 100 and the 220 yards (1/8 mile) records are better than those lying in their neighborhood, that the quarter-mile record is extremely good, the 500 yards record very bad, by comparison with its neighbors. This diagram should enable any enterprising and scientific athlete to select the records most easy to break: let him try those for 120 yards, for 500 yards, for three-quarter-mile, for three miles, but not for 220 yards, quarter-mile, one mile and six miles.

LONG-DISTANCE RECORDS

In Fig. 1 we saw that the speed fell to what seemed to be practically a constant level towards the right of the diagram: this fall

represents the initial factor in fatigue. On the logarithmic scale, however, where the longer times are compressed together, the curve continues to fall throughout its length. This later fall is due to factors quite different from those discussed above. Consideration merely of oxygen intake and oxygen debt will not suffice to explain the continued fall of the curve. Actually the curve beyond 10 miles seems to some degree doubtful. Apparently the same extent of effort has not been lavished on the longer records: the greatest athletes have confined themselves to distances not greater than 10 miles. The curve A drawn through all the points has a suspicious downward bend in it, which suggests that if Alfred Shrubb or Nurmi had tried to break the longer records they would have done so very effectively. Possibly the true curve lies more like the continuation C: possibly it may be intermediate as shown at B. It would seem doubtful, indeed, whether the running curve and the walking curve are really to meet at about 150 miles. The most probable continuation of the running curve would seem to be somewhere between the lines B and C.

The continued fall in the curve, as the effort is prolonged, is probably due to the second and third types of fatigue which we discussed above, either to the exhaustion of the material of the muscle, or to the incidental disturbances which may make a man stop before his muscular system has reached its limit. A man of average size running in a race must expend about 300 gms. of glycogen per hour; perhaps a half of this may be replaced by its equivalent of fat. After a very few hours, therefore, the whole glycogen supply of his body will be exhausted. The body, however, does not readily use fat alone as a source of energy: disturbances may arise in the metabolism; it will be necessary to feed a man with carbohydrate as the effort continues. Such feeding will be followed by digestion; disturbances of digestion may occur —other reactions may ensue. For very long distances the case is far more complex than for the shorter ones, and although, no doubt, the physiological principles can be ascertained, we do not know enough about them yet to be able further to analyze the curves.

Women's Running Records

The women's curve, as far as it goes, is very similar to the men's. Some records again are better than others. An enterprising woman athlete who wants to break a record should avoid the 300 meters; she would be well advised to try the 500 meters.

It would be very interesting to have an intermediate point between 100 and 220 yards.

Bicycling and Walking

As before, the curve for men bicycling, which is drawn on twice the scale vertically of the running curves, is far less steep than they are. The conclusion from this was emphasized above. The walking curve is interesting—it is approximately straight. Physiologically speaking, there is not much interest in the shortest walking races, since here walking is artificial and extremely laborious; running at a considerably higher speed is much more easy. For longer distances, however, say from 10 miles onwards, we have probably in walking the most reliable data available for long-continued muscular effort. If we wish to study the exhaustion produced by exercise of long duration, walking-men may well provide the best subjects for our experiments.

Skating

There remains the top curve of all, that for men skating. The initial rise of the curve, due to starting inertia, is very obvious. The fall of the curve beyond the maximum is nowhere near so rapid as for the case of running. Clearly in skating a man is not able to exert himself with the degree of ardor that is possible in the more primitive exercise of running. Skill and restraint are necessary, as they are in bicycling: there are limits to the output. Moreover, the effort can be continued for a long time, at comparatively high speeds. It is interesting to note that a man can skate 100 miles at almost the same speed as another man can run one mile. The curve falls uniformly throughout as does the walking curve. Clearly the phenomena of gradual exhaustion could be well investigated in the case of skating. Here again it is obvious which records the aspiring athlete should attempt to break.

Rowing

There are only a few records available, and those lying between rather narrow limits, for the case of rowing. Taking the case of an eight-oar boat, I have been able to obtain very few reliable data. Kennelly gives records of crews rowing, for times from 305 to 1,210 seconds. Yandell Henderson, in the *American Journal of Physiology*, vol. lxxii., p. 264, 1925, gives five observations made upon the Yale crew of 1924. In addition there are records for the Henley course: these, however, are usually contaminated by the

speed of the water. The most reliable of the data have been plotted in Fig. 1 on the same scale as the running, on five times the scale of the swimming. The observed points, shown by crosses, are somewhat scattered. As far as they go, a mean curve through them would lie practically along the curve for women swimming, but of course on five times the scale. The interesting part of the curve to the left is lacking; it is obviously impossible to make observations on an eight-oar boat for periods of 20 seconds, starting inertia is too great and no result of any value could be obtained. It would, however, be of interest to obtain data as far back as possible; certainly the records of crews rowing in still water for a minute and above should be ascertainable, and they would help to fit rowing into the scheme outlined by the other types of muscular effort.

Work and Stroke Frequency in Rowing

In rowing the movements are slow: in an eight-oar boat, from 30 to 40 strokes per minute. According to observations by Lupton and myself the maximum efficiency of human muscular movement is obtained at speeds of about one maximal movement per second. In rowing, experience and tradition alike suggest that such a speed is about the optimum. In an eight-oar boat the recovery takes almost as long as the stroke, both occupying about one second. It is of interest how practical experience has gradually evolved a speed of movement which is almost exactly what a physiologist might have predicted as the most efficient. At a stroke of about 32 per minute the mechanical efficiency is apparently near its maximum. An enormous amount of work has to be done in propelling a boat at speeds like 10 to 12 miles per hour. According to Henderson, each member of the crew of an eight-oar boat must exert about 0.6 of a horse-power. Clearly if this enormous amount of external work is to be done it must be accomplished by working under efficient conditions: those conditions necessitate a stroke of a particular frequency; only when the race is very short is it permissible, in order to obtain a greater output, to work less efficiently by adopting a more rapid stroke. The stroke may rise to 40 per minute for a short distance: in such an effort the oxygen debt is accumulating rapidly and exhaustion will soon set in. The amount of work, moreover, will not be proportionately greater, probably only slightly greater, than at the lower frequency. The conditions which determine the speed of movement, the "viscous-elastic" properties of muscle, are what ultimately decide the length of the oars and the speed of movement in a racing-boat. It is interesting

to find—as, of course, was really obvious—how closely athletics is mixed with physiology.

Wastefulness of High Speeds

This last discussion leads us to the question of what determines the great wastefulness of the higher speeds. Why, returning to Fig. 2, does a speed of 280 steps per minute require 24 liters of oxygen per minute, while a speed of 240 steps per minute requires only eight liters of oxygen? The answer depends upon the variation of external work with speed of muscular movement. In a series of recent papers it has been shown that in a maximal muscular movement the external work decreases in a linear manner as the speed of shortening increases. At sufficiently high speeds of shortening no external work at all can be performed. In most of these athletic exercises, apart from the case of rowing, a large proportion of the mechanical work is used in overcoming the viscous resistance of the muscles themselves. At high speeds of running only a small fraction of the mechanical energy of the muscles is available to propel the body, once the initial inertia has been overcome. The speed of shortening is so rapid that little external work can be done. The work is absorbed by internal friction, or by those molecular changes which, when the muscle is shortening rapidly, cause its tension to fall off. When working against an external resistance, as in rowing, there is an optimum speed. If an effort is to be long continued it must be made at a speed not far from the optimum. When, however, the whole of the resistance to movement is internal, as in running, there is no optimum speed: the expense of the movement increases continually as the speed goes up; the faster we move, the greater relatively the price: our footsteps are dogged by the viscous-elastic properties of muscle, which prevent us from moving too fast, which save us from breaking ourselves while we are attempting to break a record.

Uniform Speed is the Optimum

The amount of energy required per minute to run or to swim, or, indeed, to propel oneself in any way, increases more rapidly than the speed—in the cases which have been investigated, approximately as the square of the speed. This mathematical relation is not exact: the facts can only really be described by a curve such as that of Fig. 2, but it simplifies the argument. From the form of the curve of Fig. 2, or from the variation of energy output as the square of the speed, we can immediately deduce that the most efficient way in which to run a race is that of a uniform speed

throughout. Imagine that a man runs a mile race in 4 minutes 30 seconds at a uniform speed of 6.52 yards per second: his energy expenditure is proportional to 4½ times 6.52 squared; that is, 191.3 expressed in some arbitrary units. Imagine now that he runs it at two speeds, 6 and 7 yards per second, 780 yards at the lower, 980 at the upper speed: the total time is the same; the energy expended, however, is slightly greater, 192.3 instead of 191.3. This small variation of speed in the race has produced no serious increase in the energy expenditure. Let us imagine, however, that one portion of the race, 665 yards, is run at 5 yards per second, while another portion, 1,096 yards, is run at 8 yards per second. The total time occupied in the race is still 4 minutes 30 seconds. The energy expended, however, is greater, namely, 201.5 units. Even this, however, is not a very large increase; by running about half the time at 8 yards and half the time at 5 yards per second, the energy expended has been increased only about 5 per cent. as compared with that required for running at a uniform speed of 6.5 yards per second throughout. Although, therefore, theoretically speaking, the optimum fashion in which to run a race is that of uniform velocity throughout, comparatively large variations on either side of this velocity do not appreciably increase the amount of energy expended.

Possible Advantages of a Fast Start

There may, indeed, be advantages in starting rather faster than the average speed which it is intended to maintain. The sooner the respiration and circulation are driven up to their maximum values, the greater will be the amount of oxygen taken in by the body, the greater the amount expendible during the race. It is a common practice in mile races to start very fast and to settle down later to the uniform speed: this may have a physiological basis in the quickening up of circulation and respiration achieved thereby.

The Simple Mechanics of High-Jumping

One final point may be worthy of mention—this time connected with high-jumping and long-jumping. Recently I made a series of observations, with a stop-watch reading to 0.02 seconds, of the times occupied by a number of high-jumpers from the moment they left the ground to the moment they reached the ground again. With men jumping about five feet the time average about 0.80 second. Calculating from the formula

$$S = \tfrac{1}{2}gt^2,$$

where t is half the total time of flight, the distance through which the center of gravity of the body was raised must have been about 2.5 feet. The men competing must have had an original height of their center of gravity of about 2.7 feet. Thus, in the high-jump, their centers of gravity went about 5.2 feet high into the air. They cleared a height of five feet: they just managed to wriggle their centers over the bar. Now, paradoxical as it may seem, it is possible for an object to pass over a bar while its center of gravity passes beneath; every particle in the object may go over the bar and yet the whole time its center of gravity may be below. A rope running over a pulley and falling the other side is an obvious example. It is conceivable that by suitable contortions the more accomplished high-jumpers may clear the bar without getting their centers of gravity above or appreciably above it. Let us calculate, however, on the assumption that the center of gravity of a jumper just clears the bar. The world's record high-jump is 6.61 feet, the center of gravity of the performer being presumably about 3 feet high at rest. He raises it therefore 3.61 feet into the air, from which we may calculate that the whole time occupied in the jump is about 0.96 second. Seeing the amazing complexity of and the skill involved in the rapid movements and adjustments involved in a record high-jump, it is striking that all those events can occur within a time of less than one second. All the characteristics of the proprioceptive system must be evoked in their highest degree in carrying out such a skilled, rapid and yet violent movement.

Long-Jumping

It is well known to athletes that success in long-jumping consists in learning to jump high. It is not, of course, the case that a record long-jumper performs at the same moment a record high-jump. He must, however, cover a very considerable height. The world's record long-jump is 25.48 feet. With the check provided by the vertical impulse in the last step we can not well imagine the horizontal velocity to be greater, at this moment, than that of 100 yards completed in 10 seconds; that is, than 30 feet per second. Let us assume this value: then the performer remains in the air for $\frac{25.48}{30}$; that is, 0.85 second: hence we may calculate that the vertical distance covered is about 2.9 feet. Assuming the center of gravity of the subject to have been originally 3 feet high, this means that it must have reached a height 5.9 feet in the air, enough, in a high-jump, to enable its owner to clear 5.9 feet. It is interesting to find that the simple laws of mechanics emphasize so strongly

the precepts of the athletic trainer. Not only must one jump high if one wishes to break a long-jump record, but one must bring one's center of gravity nearly six feet high into the air; for one must project oneself vertically, so that one may remain for 0.85 second above the ground.

Conclusion

The practice of athletics is both a science and an art, and, just as art and science are the most potent ties tending to draw men together in a world of industrial competition, so sport and athletics, by urging men to friendly rivalry, may help to avert the bitterness resulting from less peaceful struggles. If, therefore, physiology can aid in the development of athletics as a science and an art, I think it will deserve well of mankind. As in all these things, however, the reward will be reciprocal. Obviously in the data of athletic records we have a store of information available for physiological study. Apart from its usefulness, however, I would urge that the study is amusing. Most people are interested, at any rate in England and America, in some type of sport. If they can be made to find it more interesting, as I have found it, by a scientific contemplation of the things which every sportsman knows, then that extra interest is its own defense.

SHELL-MOUNDS AND CHANGES IN THE SHELLS COMPOSING THEM

By EDWARD S. MORSE
SALEM, MASSACHUSETTS

The refuse piles of early races are scattered along the coast line of every continent. They are mainly composed of the shells of edible mollusks. Little attention was paid to them until Professor Steenstrup, the eminent Danish naturalist, was led to examine a number of these deposits along the shore of the Baltic Sea. These masses of shells along the shore lines had been regarded as natural configurations due to the elevation of the land and had been known in various parts of the world as upraised beaches. Steenstrup soon discovered that the shells composing these deposits were full grown, or nearly so; he also observed that the mass consisted of shells of four edible species and that these mollusks did not live in the same habitat or stretch of shore, some like the oyster living on rockbeds, others in sand. By this study the artificial character of the shell-heaps was established. Sir John Lubbock visited the Baltic shell-heaps with Steenstrup and in his classical work, "Prehistoric Times," he devotes a chapter to the subject, and in this chapter the student will find a most lucid account of Steenstrup's work.

The exploration of shell-heaps in various parts of the world has brought to light many objects of human workmanship, and though these deposits are literally the refuse piles or kitchen refuse of a rude and savage people, and most of the objects are in a fragmentary condition they have, nevertheless, thrown much light on the culture of the people who made them. A study of the bones and charred wood indicates a great change in the fauna and flora of the region since the deposits were made. A study of the shells composing these deposits shows that a change has taken place in the relative abundance of individuals of certain species, and in their relative size, relative proportions and in the extinction of certain species.

In a rather extensive study of the shell-mounds of Omori, near Tokyo, which I was first to recognize as an artificial deposit, and upon which I prepared a memoir which was published by the Imperial University, I found a marked variation in the amount of proportional change in the different species. A marked change was also seen in the relative abundance of certain species. One species

of shell, rare in the mounds, is common along the shores of Yedo Bay; three species common in the mounds are not found in Yedo Bay; two species common in the mounds are rare to-day; seven species are equally common in the mounds and living along the shores; seven species common in the Tokyo market are not found in the mounds and one species, *Arca granosa,* is not found living within five hundred miles of the mounds.

In the New England shell-heaps the common Pecten, or scallop, is found as far north as Maine, yet it is a southern shell and does not live north of Cape Cod, except at the extremity of the cape, where it is very abundant and extends a little way round on the northern shore. *Venus mercenaria,* the quahog, is found living in a few localities north of Cape Cod; formerly it must have been common along the whole coast as nearly every shell-heap revealed it. At the time the shell-heaps were formed in Casco Bay, Maine, the region was covered wtih a hard-wood growth; not only is this shown by the character of the charcoal, but a close examination of the original ground surface, under a deposit of shells five feet in thickness, shows several species of minute land shells that live only in hard-wood growths. Now, and from the earliest historic times, pine and spruce have covered the land. In the Baltic shell-heaps oak was the prevailing tree of the forest. Since the earliest historic records in Denmark beech has been the prevailing tree. The great auk, a northern bird, has long been extinct, yet in the shell-heap times it was common along the eastern coast of America even as far south as Florida, as is shown by the bones of the bird often found in the heaps.

Steenstrup gives a list of seven species of shells found in the Baltic shell-heaps and says, "It is remarkable that they are well developed and larger than any found in the neighborhood." The mass of the deposits is composed of oyster shells and this shell has entirely disappeared from the Baltic; the common clam, *Mya arenaria,* found everywhere in the Baltic, was not found in the shell-heaps. I visited Professor Steenstrup to ascertain how I could reach the Baltic shell-heaps and he told me that they had all been dug over and the relics all collected. I told him I was interested only in getting the shells of the common clam, and to my amazement he said there were no shells of Mya in the deposit. Though the clam abounded in the Baltic the prehistoric people never ate them. It was the same in England; the clam had never been eaten, even in ancient times. It is a common shell there, and thousands of barrels are shipped to the Newfoundland fisheries for bait. We learned the epicurean delights of the clam from the North American Indians, to whom we are indebted for the divine gift, tobacco.

Professor Jeffries Wyman observed several changes in the shells of the Florida shell-heaps. He says, in his memoir of the subject, that the Ampullaria and Paludinae are much larger than those living in the immediate vicinity.

Clarence Bloomfield Moore, who has made extensive explorations of the shell-mounds of Florida, in the *American Naturalist* for 1892 (Nov., p. 192), describes shell-heaps on the St. Johns River. He says: "It will be noted that the aperture of the shell, in specimens from the mound, measures from one half to about one third the length of the shell; but in recent specimens, from the adjacent creek, it is in every case over one half the shell's length. No living specimens on record attain the size of the average shells of some of the mounds."

It has been shown that any change in the normal physical surroundings of an animal effects a change in the size or form of a creature in proportion to the intensity of conditions affecting it. Species vary greatly in their susceptibility to these conditions. In some species, as shown by Bateson in his studies of the upraised beaches of the Aral Sea, no changes are observable; while *Cardium edule* has been profoundly modified, *Dreissina polymorpha* and *Hydrobia ulvae* have shown no change. The changes in the proportionate diameters of many of the species of shells in the deposits lining the Gulf of Maine, Massachusetts Bay, Long Island Sound and the Bay of Yedo can not be due to changes in the chemical content of the water, for these bodies of water are too vast to be subjected to such influences as affected the Baltic Sea, the Aral Sea and the Champlain Valley in glacial times. Temperature alone must be regarded as the physical cause, as it will be shown that the proportionate diameters of Mya and Natica vary north and south of Cape Cod where the waters vary greatly in temperature. In the glacial clays of Maine, Mya has an index of 66 correlated with the lower temperature of glacial waters. Sir William Dawson, in the Canadian Record of Science, 1889, records the finding of the long variety of *Mya truncata* in shallow and warm water habitats, while in the colder waters the short variety occurs.

The shell-heaps at Damariscotta, Maine, composed almost entirely of oyster shells, are among the largest on the coast[1] and one has to go to Florida to find any of equal size. The greatest height of the deposit at Damariscotta was thirty-five feet. The early shell-heaps along the coast of New England, especially north of Cape Cod, were made up of the shells of the common clam, *Mya arenaria,* and these deposits rarely exceed five feet in thickness. A very interesting feature of the Damariscotta deposits is the indisputable evidences of great age. This is determined by measuring the shells

[1] Removed for agricultural purposes.

of Mya, which are scattered through the deposits from the upper layers through to the very bottom layers. The results of these measurements proved that a change had taken place in their proportionate diameters during the growth of the deposits, and the earlier shells had a higher index than those found in the upper layers. So marked was the difference that the workmen engaged in removing the mass of shells averred that they had noticed that the clams in the base of the deposits were not only smaller but rounder.

In collecting the shells of Mya from the shell-heaps it is noticed that many are deformed by injuries, the result of the ruder methods employed by the Indians in using a pointed stick in prying them up from the mud. The clam digger to-day uses a four-pronged rake and pulls up a mass of clay from which he disengages the clams and thus avoids to a great extent the breaking of the shell. In measuring the clam I selected only those that were full grown, and of those only the toothless or right valves; furthermore, in choosing those for measurement, I selected only those shells that had perfect anterior and posterior margins.

I had a table extending the entire length of a thirty-foot room, along the edge of which I inserted measuring sticks having marked on them a scale of millimeters. The face of this measuring surface was on a level with the table, the shells were laid along the table, first longitudinally, the anterior and posterior edges of these shells just touching, the shells so placed that the ventral edge of one shell was in line with the dorsal side of the next one. Fifty or sixty shells were measured at one time. The point was to ascertain the proportional diameters: assuming the length of the shell to be 100, what was the height, that is, from the ventral edge of the shell to the beak? This was called the index. Now in every instance the index was higher in the shell-heap Mya than in the recent forms. The Mya in the shell-mounds of Omori, Japan, varied in precisely the same direction.

In a very interesting memoir, by William Bateson (Philo. Trans. 1889), on "Some variations of *Cardium edule,* apparently correlated to the conditions of life," he has shown some profound modifications which the shell has undergone in the drying up of certain lake regions around the Aral Sea with corresponding changes to be found in a series of terraces which, so to speak, formed a chronological sequence of beds. Among other interesting facts brought out by Mr. Bateson was the evidence already mentioned that while these changing conditions were correlated with the modifications of the shells of *Cardium edule* no appreciable change was observed in the shells of *Dreissina polymorpha* and *Hydrobia ulvae.* The physical changes taking place were an increased salinity of the

water and the shoaling of the water areas and a rise and greater variation of temperature. These changed physical conditions were correlated with the lengthening of the shell as compared to its height, a diminution in size and a reduction in the number of ribs.

In measuring the coiled shells, like Natica, the length and the breadth of the shell are indicated by the lines A, B and C.D in Fig. 1. A surface marked by closely ruled parallel lines will aid in adjusting the shell for measurement. Select only those shells that have the tip of the apex and base of the aperture unbroken, and then arrange them in the following manner: first ascertain the length (Fig. 2) and then their breadth as in Fig. 3. The eye is used in adjusting the shells for measurement and hence it is easier to have the closely ruled lines so that the shells can be more easily aligned. The difference in proportionate diameters are so great in most of the genera that this rough way of measurement is sufficiently accurate for the purpose.

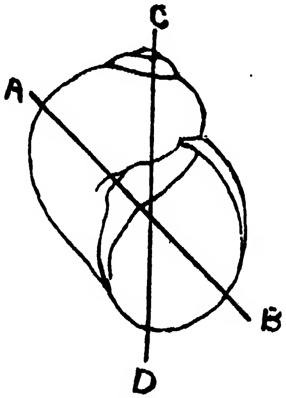


FIG. 1

I have collected my material from various shell-heaps along the shores of Maine, Massachusetts, Rhode Island and Connecticut. The Indians who made these deposits always established their camps in close proximity to mud-flats in which clams abounded, and usually where springs of water were found. It was assumed that the shells composing the shell-heaps were the ancestors of the clams

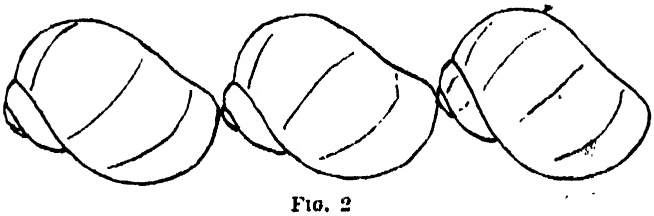


FIG. 2

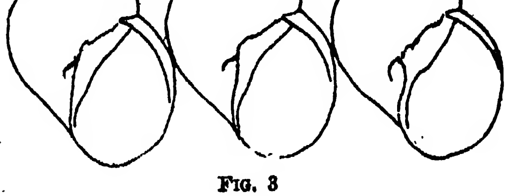


FIG. 3

living in the immediate vicinity. In collecting the shells from the shell-heaps I made a similar collection of the living clams along the

adjacent shore. While the average index of the recent clam was 61.23, the shell heap clam was 63.37,[2] and if the index was higher in the ancient shell the recent shell on the neighboring shore in every case was also higher. As an example, the index of the clam in a shell-heap on Clapboard Island, Casco Bay, Maine, was extremely high, being nearly 64; in the living clam in the immediate vicinity the index was also high, being nearly 63; at Bar Harbor, Maine, the index of the shell-heap clam was 65, while the recent clam in the immediate vicinity was 63—striking evidences that the ancient clam was the direct ancestor of the clam living in the

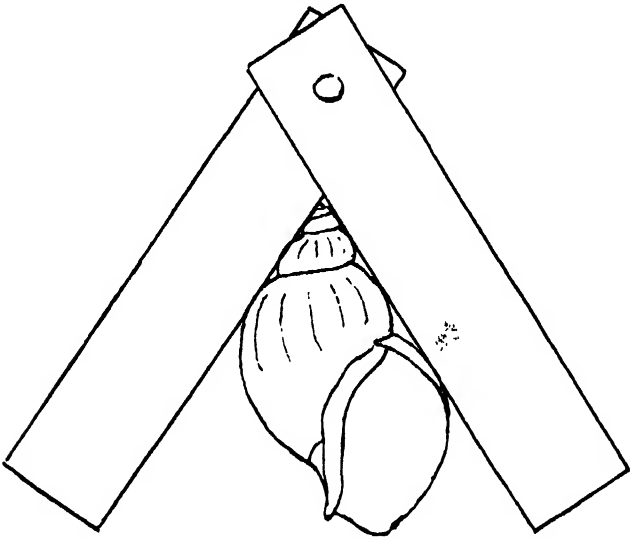


FIG. 4

vicinity to-day. The index of the recent clam north of Cape Cod is higher than the recent clam south of Cape Cod. The temperature of the waters south of Cape Cod is much higher than that of the waters north of the Cape. If then the index is correlated with temperature, the Mya in glacial clays should have a very high index; and this I found to be so in measuring shells of Mya from the glacial clays in Maine, specimens from glacial clays in the museum at Upsala, Sweden, and at Brighton, England, the index was 65 and 66.

[2] From twelve shell-mounds along the coast from Penobscot Bay, Maine, to Marblehead, Massachusetts, I measured 904 specimens of the common clam, *Mya arenaria*, and the average index was 63.37; from the adjacent shores of these mounds I got 976 specimens and the average index of these was 61.23. These were north of Cape Cod; south of Cape Cod I got from one station only seven perfect specimens, altogether too small a number to estimate upon. The average index, however, was 61.21, and of 302 recent clams, south of Cape Cod, the average index was 60.20.

Lunatia heros was not very common in the Marblehead shell-heap, which was a very small deposit. I managed to get thirty perfect specimens, and on the shore I picked thirty shells at random. The following list in millimeters is the measurements of these shells in the manner illustrated in Fig. 1. These figures run from the largest to the smallest shells collected.

In measuring coiled shells to ascertain the angle of the spire a simple device can be made of two strips of brass, or zinc, held together at one end by a rivet so that it can be opened or closed (Fig. 4). This device can be pushed down over the spire and then placed on the paper and the angle traced. With this I measured a number of species, and in every case the angle was less acute than in the recent form. Fig. 5 shows the angle of *Eburna japonica*, a common shell in the Omori shell-mounds and equally

Lunatia heros. Pine Grove, Marblehead, Massachusetts

Recent		Ancient	
Height	Breadth	Height	Breadth
51	49	48	44
51	49	48	43
39	39	48	43
39	39	46	41
39	38	45	41
38	38	44	40
38	38	43	39
37	37	43	39
37	37	42	39
36	36	42	38
35	35	42	37
35	34	41	37
34	34	41	37
34	34	41	36
34	34	40	36
34	34	40	36
34	33	40	36
33	33	40	36
33	32	40	35
33	32	40	35
32	32	39	35
32	31	39	35
32	30	39	35
31	30	38	34
31	28	38	34
29	28	37	33
29	27	37	33
28	27	36	33
28	26	36	33
27	25	36	33

common along the adjacent shore. These angles represent the mean angle of hundreds measured; the inside line shows the angle of the recent form and the outside angle the ancient. In the New England shell-heaps the nearest relative of Eburna is *Buccinum undatum,* the shell shown in Fig. 4. It is very scarce in the mounds. Yet in the few measured the index was higher. On one island near Mount Desert, Maine, in a shell-heap I found 25 specimens and collected the same number on the beach, hardly enough to measure, yet the result was the same; the ancient shell had the less acute spire. The largest convoluted shells in New England are two species of Busycon, six or seven inches in length. These have never been found north of Cape Cod. The few I was able to get in a shell-heap south of Cape Cod distinctly showed a flatter spire.

A little black shell with eroded apex, *Nassa obsoleta,* is found living exclusively on mud-flats. It is also found in the shell-heaps and in such abundance sometimes that they must have been used for food. In an ancient deposit at Narragansett Pier, Rhode Island, I collected 284 specimens of this shell and on the adjacent mud-flats I collected an equal number, measuring them in the manner already described. I found the index in the recent shell was 55.8, while in the ancient form it was 56.7. In the Marblehead, Massachusetts, shell-heap I got 245 specimens of this shell, and on the mud-flats I collected 181 specimens; the index in the recent shell was 57.1 and in the ancient shell 58.5. The higher the index the less acute is the angle of the spire. The difference is slight, yet in both cases the recent shell has the more acute spire. The apex was eroded in the ancient and recent shell; in the Marblehead specimens the shells varied greatly in form; 134 were quite smooth, 49 were excessively eroded, and 62 had heavy folds. The ancient shell was longer, the average length being 21.50, while the recent form was 18.

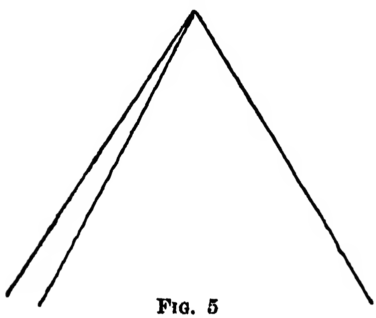


FIG. 5

The large whelk, Buccinum, is rare in the mounds. On one island near Mount Desert, Maine, in a shell-heap I found 25 specimens and collected the same number on the beach, hardly enough to measure, yet the result was the same; the ancient shell had the less acute spire.

The changes in size and shape of the species of shells in the Omori deposits were so marked in contrast with the recent shells that they could be easily recognized along the beach where they had

been washed from the mounds. The different species varied in the size and proportion of their changes. In some the ancient forms were larger than the recent. In others they were smaller; in some species the changes were profound. Thus in the three species of Arca the ribs have increased in number.

	Ancient	Recent
Arca-sub-crenata	30	33
" -inflata	39	41
" -granosa	20	26

In *Arca inflata* the hinge area, or deck, in a single valve is 15 mm wide in the ancient form, while in the recent form it has been reduced to 5 mm. In the coiled shells the difference consisted in a more obtuse spire in the canaliculated forms in the shell-heap, while in the recent forms the spire was more acute.

It is interesting to remark that the *Purpura luteostoma* and *P. clavigera* are easily distinguished from one another in the recent forms collected at Enoshima and other places along the coast. In the shell-heaps the distinctions are not so easily made out, and it would seem that *Purpura perone*, *P. luteostoma*, *P. clavigera*, *P. tumulosa* and others were modifications of a single form.

In the Omori shell-mounds *Natica lamarckiana* was so different from the recent form that it might be regarded as a marked variety. The shell was equally abundant in the shell-heap and along the shore. In the ancient form the spire is much higher than in the recent form (Fig. 6). In the shell-heaps of New England a closely allied species, *Natica duplicata*, shows precisely the same change, as does also *Natica heros*. Fig. 7 is a photograph of eight specimens of *Natica heros*; the four on the left are from a shell-heap near Salem, the other four picked up from an adjacent beach, the ancient form having a much higher spire. I collected thirty-four specimens and picked up at random from the adjacent beach the same number and measured them. It will be seen that the length of the shell-heap Natica is much longer compared to its width than in the recent shell.

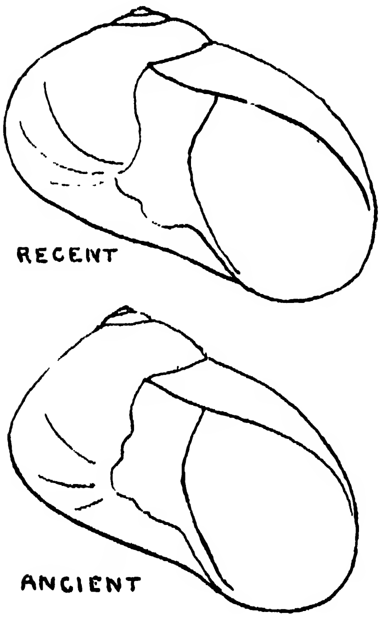
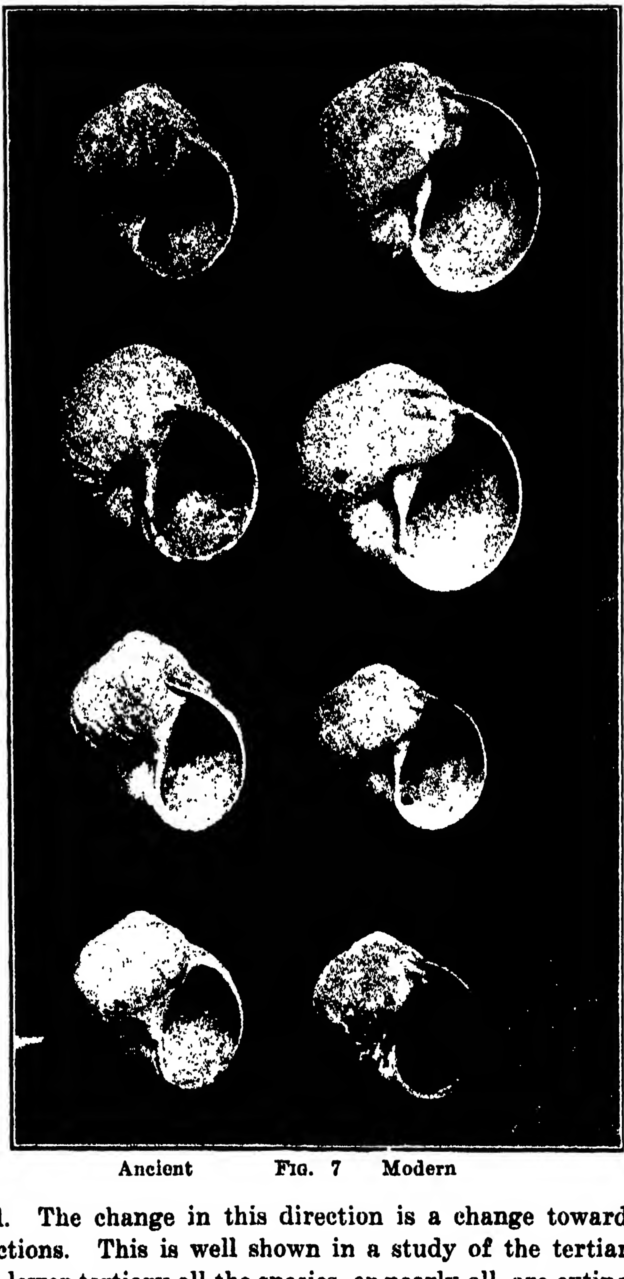


FIG. 6

The question of size alone would indicate matters of nutrition and the salinity of the water, and these variations might occur in a few generations. Changes in proportionate diameters imply a longer



Ancient FIG. 7 Modern

period. The change in this direction is a change toward specific distinctions. This is well shown in a study of the tertiary shells. In the lower tertiary all the species, or nearly all, are extinct; in the middle tertiary from 40 to 60 per cent. are extinct, in the upper

tertiary none, or but few, are extinct and in recent times the process goes on in a change in the proportionate diameters of the shell.

In an exceedingly interesting memoir, entitled "The Champlain Sea," by Miss Winifred Goldring,[3] the author has made an exhaustive study of the Pleistocene shells along the banks of the St. Lawrence and Champlain Valley, and has brought out the fact that going southward there is evidence of a marked change in the Pleistocene fauna similar to that seen in the living fauna of the Baltic Sea to-day. "A study of this fauna and comparison with the conditions found in the Baltic Sea and elsewhere, has led to the conclusion that the character of the post-glacial marine fauna is due in large part, at least, in the decreased salinity in this direction in the waters of that time. . . . The normal salt composition of sea water permits the development of a fauna rich in species and genera. A reduction of the salt content produces an impoverished fauna, poor in lime, dwarfed in size but often rich in individuals." In a graphic way the author has given the outlines of various genera, such as Macoma, Saxicava, Yoldia and others superimposed upon each other, showing the diminishing size of the specimens as the habitat receded from the normal salt content of the water to the southern region of the Champlain Valley and consequent freshening of the water. Not only does the freshening of the water dwarf the individual, but the proportionate diameters of some of the species have changed. Miss Goldring shows that "in *Yoldia actica,* from the Champlain area the modified form of the shell is very noticeable. . . . In the recent forms and those from Montreal and Ottawa areas there is a pronounced posterior extension or wing with subacute tip. . . . The extreme forms of the Champlain area are so different from the typical forms from the vicinity of Montreal and Ottawa that we will be inclined to regard them as belonging to another species."

In an interesting paper by Professor Henry W. Shimer, entitled "Dwarf faunas,"[4] an excellent résumé is given of many contributions on the subject. He says that physical conditions modified the character of the individual and all these species appeared dwarfed. The following are the chief agencies of dwarfing as noticed in recent and fossil faunas; a change in the normal chemical content of the water, such as freshening, concentrations of salt, iron, etc.; increase in certain gases, presence of mud and other mechanical impurities; variation in temperature, a floating habitat and extremes in depth of water. It seems curious that all these various influences

[3] New York State Museum Bull. 230, 240, seventeenth report of the director.

[4] *American Naturalist,* Vol. XLII, No. 499.

should modify the individual in one general way, namely, in dwarfing, in some instances causing deformities. William Bateson in his memoir entitled "On some variations of *Cardium edule*, apparently correlated to the conditions" (Philosophical Trans., 1889), says, "If by this examination any variation can be shown to occur regularly with the change of conditions or in any way in proportion to their intensity, it is so far evidence that there is a relation of cause and effect between them."

In my memoir on "The shell-mounds of Omori," I prepared a chapter entitled "A comparison between the ancient and modern molluscan fauna of Omori, Japan." Realizing that Charles Darwin would be interested in the evolutionary facts therein contained, I ventured to send him page proofs of the chapter with a plate figuring nine species, at the same time begging him not to acknowledge them. Nevertheless, I received the following letter which I can not refrain from publishing, as it has already appeared in the "Life and Letters of Charles Darwin."

> Although you are so kind as to tell me not to write I must just thank you for the proofs of your paper which has interested me greatly. The increase in the number of ridges in the three species of Arca seems to me a very noteworthy fact; as does the increase of size in so many yet not all the species. What a constant state of fluctuation the whole organic world seems to be in! It is interesting to hear that everywhere the first change apparently is in the proportional numbers of the species: I was much struck with this fact in the upraised shells at Coquinbo, in Chile, as mentioned in my geological observations in South America.
>
> Of all the wonders of the world the progress of Japan, in which you have been aiding, seems to me about the most wonderful.
>
> Believe me
my dear Sir
yours very truly
Charles Darwin.

The changes we have seen in the proportionate diameters, relative size, abundance, etc., of the species of shells composing the shell-heaps in America and Japan indicate a vast lapse of time since the first deposits were made. Steenstrup believed that the Baltic shell-heaps belonged to the early stone age. The few stone implements found in the Omori, Japan, deposits were of the rudest character. The changes in the shape of the shells are an important illustration of the fact that when you have a unit of time sufficiently long species change, a significant fact for evolution.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

AFTER A

FOR more than a dozen years chemists have been hunting for something that nobody has ever seen and yet everybody has to have. It is in our food; must be or else we starve with our stomach full. In lack of it, the white rat babies of the laboratory—and, what's worse, white human babies by the thousand—may die an early death or be stunted for life. Our sense of taste, which is generally a safe guide to nutritive values, fails us in the case of the vitamins, for we can not tell by the savor which foods contain these essential ingredients, yet if we fail to include such foods in our daily dietary we soon suffer for it in health and vigor.

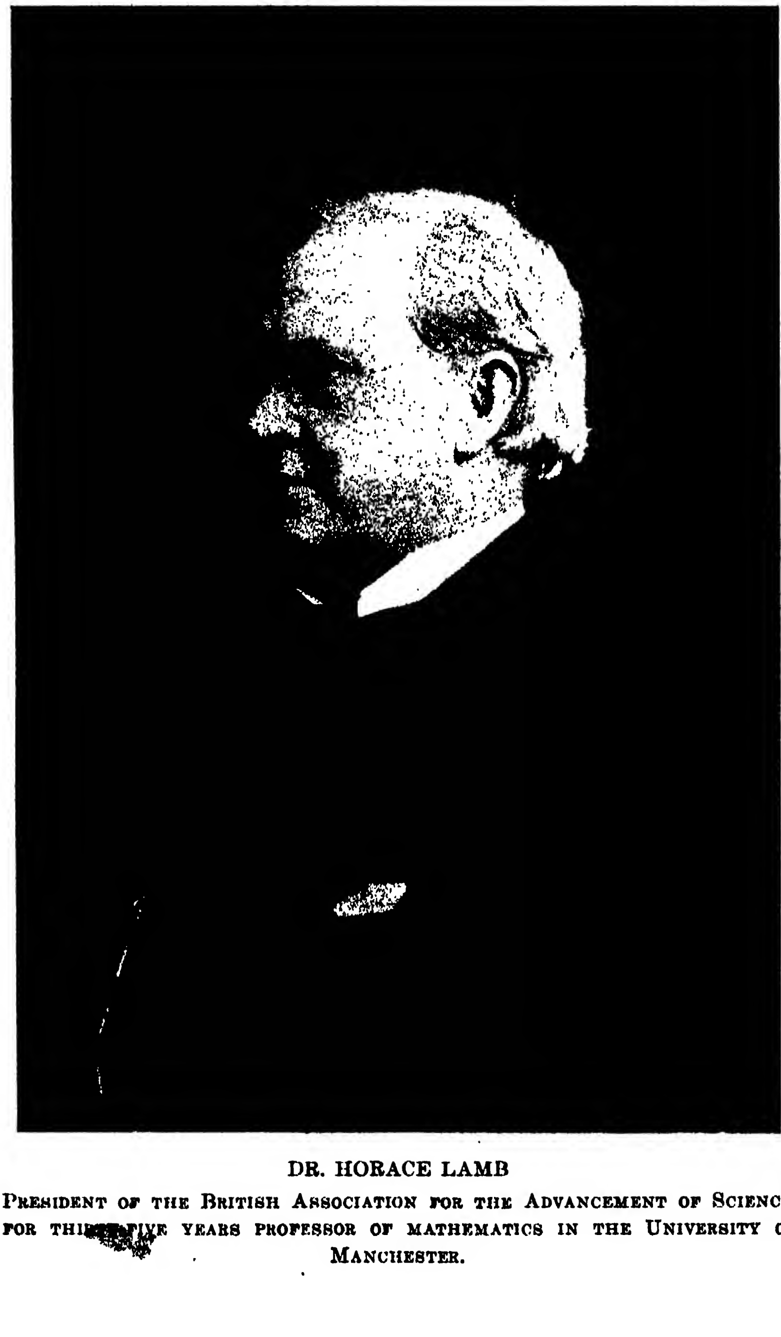
At the head of the list of vitamins is that known provisionally as "A." Chemists could not give it its proper name because they did not know what family of compounds it belonged to. They only knew that certain foods were short of something essential for growth and health.

Their problem was like the riddles that used to be popular with puzzlers. For instance: "My first is in butter, but not in lard." It is in sweet potatoes, but not in Irish. It is in yellow corn, but not in white. It is in codliver oil, but not in olive oil. What is it?

McCullom, of Madison, who found out these facts about 1912, called the evasive vitamin "unidentified dietary factor fat-soluble A," which expressed what was known at that time, but obviously was not the sort of snappy slogan that the advertiser of a breakfast food desires. Chemists all over the world have been trying ever since to isolate and purify Vitamin A, but unsuccessfully.

At last, however, the problem appears to have been solved and Japan may get the honor of isolating "A." Katsumi Takahashi and other investigators, working in the laboratory of Professor U. Suzuki in the Institute of Physical and Chemical Research at Tokyo, report having extracted and analyzed Vitamin A from codliver oil, spinach and green laver, a seaweed. It comes out finally as a yellowish red oil, transparent and viscous, with a characteristic but not disagreeable odor and a slightly bitter taste, resembling somewhat the yellow matter of carrots and green leaves. It is not so unstable as had been supposed, for it can be distilled in a vacuum without decomposition.

The courtesy of chemistry gives to the discoverer of a compound, like the father of a child, the right to christen it, and fortunately for the rest of the world, the Japanese chemists have not insisted upon giving their find a Japanese name. They have instead called it "biosterin" because it resembles in composition and behavior the already known "cholesterin," which occurs commonly in plant and animal cells, although its function is still a mystery.



DR. HORACE LAMB

President of the British Association for the Advancement of Science, for thirty-five years professor of mathematics in the University of Manchester.

One of the interesting peculiarities of biosterin is that it will print its image on a photographic plate in the dark. That is, it acts like radium in giving off some sort of active rays or emanation capable of producing an impression on the sensitive plate as light does. Various oils and terpenes will act like this, but none of them are so active.

The effect of a minute amount of biosterin on the vital processes is most amazing. A daily dose of no more than a millionth of a gram was sufficient to keep up the growth of young rats that were fed on a diet so deficient in this vitamin that they would otherwise stop growing and die. But, on the other hand, rats that took a drop too much died of it, like those who had none. The fatal dose is about ten thousand times the normal ration, so there is ample margin and no one is endangered by getting an overdose of biosterin in his food.

If this turns out to be really the long sought vitamin, it will mark the beginning of a new era in food science for chemists. When the chemist gets hold of a definite compound, he may make it in quantity, or others similar to it, which may have different effects. To be able to alter the nutritive value and influence of a diet by adding a drop or two of something puts into the hands of the chemist a new power of controlling the processes of life that may lead to strange results.

WAKING UP THE DEAD SEA

Among the many schemes for the development of Palestine one of the most original and ambitious is that for utilizing the Dead Sea as a source of water power.

This seems at first sight a startling suggestion. We are used to getting water power from mountain streams and lakes, but the Dead Sea is about 1,300 feet below the ocean level to start with.

But on second thought, we see that the scheme is not theoretically impossible, for if we can get power from water running down to the ocean, we can likewise get power from water running down from the ocean—provided that we can find a lower place to put it in. Even if we could find a sink at low level in which to run the waste water there would have to be some pumping arrangement to lift out the water as fast as it runs in, and this would require more power than could be got out of the water wheel.

Now the Dead Sea forms just such a sink as is needed and an adequate pump was long ago installed by providence and is already in operation, being supplied with power by the central station of the solar system. The sun sucks up the river Jordan as rapidly as it runs in and the engineers calculate that if as much water as this or more were siphoned in from the Mediterranean, it would be continuously evaporated from the expanded surface of the sea and the soaked sands of its shore. This is expected to provide over 600,000 horse-power for the electrification of the Holy Land.

The French Academy of Sciences, before which this scheme was presented, considered also the power possibilities of the other sub-sea sinks of the world, especially the Salton Sea, the Caspian Sea and certain sections of the Sahara.

The Salton Sea was formed or rather refilled about twenty years ago by flooding from the Imperial irrigation canal and the Alamo and New Rivers and it has been slowly drying up ever since. The surface is 206 feet below the Gulf of California. In 1917 its area was 300 square miles.

International News Reel Photos

DR. CHARLES W. ELIOT

PRESIDENT EMERITUS OF HARVARD UNIVERSITY, POSING FOR A PORTRAIT BUST BEING EXECUTED BY MR. C. S. PAOLO, OF NEW YORK. ON THE OCCASION OF DR. ELIOT'S NINETIETH BIRTHDAY LAST YEAR GREETINGS WERE SENT FROM A LARGE NUMBER OF SOCIETIES AND OTHER ORGANIZATIONS, AND THESE HAVE BEEN PUBLISHED IN A COMMEMORATIVE VOLUME.

It is, therefore, about as large as the Dead Sea but only a sixth as deep below sea-level. The evaporation rate at Salton Sea is about half that of the Dead Sea, so the total theoretical horse-power obtainable by running into the Salton Sea from the Gulf of California, ninety miles distant, all the water that can be evaporated away would not produce over 35,000 horse-power. But it is useless to talk about the project anyhow, for the Californians would lynch any one who proposed to turn the Salton Sea into a salt sea permanently, when it could be better used as farming land. They are determined that no more water shall be run into their sink.

The idea of making a sea out of the Sahara was much discussed in the last century, not for the purposes of power, but to open up the heart of Africa to navigation, make a seaport out of Timbuctoo, and ameliorate the climate. It was argued that it was only necessary to cut through a narrow rim of north Africa and let in the waters of the Mediterranean, which would form there a second Mediterranean, surrounded by fertile shores and flourishing cities. The British protested that flooding the Sahara would divert the Gulf Stream into the Straits of Gibraltar and leave England as cold as Labrador.

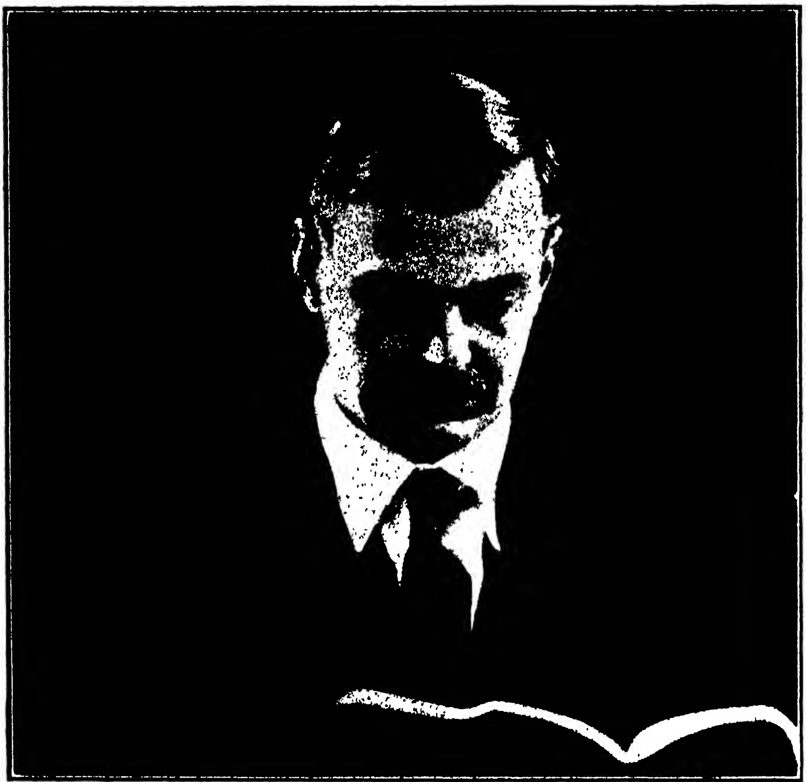
But both the hopes and the fears vanished when some one took the trouble to look at a topographic map of Africa and observed that the average altitude of land proposed to be submerged was over a thousand feet. Only a very small portion of the Sahara is below sea level; certain salt marshes in southern Tunis and half a dozen oases in eastern Libya, and these were only from fifty to a hundred feet below the Mediterranean.

So the great project for the navigation of the Sahara collapsed and is now principally remembered because it afforded Ibsen a theme for one of Peer Gynt's chimerical schemes. This is his vision as a penniless castaway in Morocco:

> "The sea's to the west; it lies piled up behind me,
> Dammed out from the desert by a sloping ridge."
>
> "Dammed out? It wants but a gap, a canal,—
> Like a flood of life would the waters rush
> In through the channel, and fill the desert!
> Soon would the whole of yon red-hot grave
> Spread forth, a breezy and rippling sea.
> The oases would rise in the midst, like islands;
> Atlas would tower in green cliffs on the north:
> Sailing ships would, like stray birds on the wing,
> Skim to the south, on the caravans' track."
>
> "The southland, behind the Sahara's wall,
> Would make a new seaboard for civilization.
> Steam would set Timbuctoo's factories spinning."
>
> "Skirting a bay, on a shelving strand,
> I'll build the chief city, Peeropolis.
> The world is decrepit! Now comes the turn
> Of Gyntiana, my virgin land!"

A PAYING GUEST

A NEW and startling theory of how we got our good red blood is advanced by Mr. Needham, of Cambridge. He suggests that the red corpuscles, now a necessary factor in animal life, first entered as foreign invaders in search of food. Sometime back in the Pre-Cambrian, he surmises, when the ancestors of all mammals were still swimimng in the sea and had not yet closed their circulatory system, they were penetrated by certain single and free-swimming cells,



DR. CLARENCE C. LITTLE

ELECTED PRESIDENT OF THE UNIVERSITY OF MICHIGAN, WHILE OCCUPYING THE PRESIDENCY OF THE UNIVERSITY OF MAINE. PREVIOUSLY DR. LITTLE WAS ASSISTANT DIRECTOR OF THE STATION FOR EXPERIMENTAL EVOLUTION OF THE CARNEGIE INSTITUTION WHERE HE CARRIED ON IMPORTANT WORK IN GENETICS

which, finding here abundance of nitrogenous nutriment, made themselves at home and in time became indispensable to their host. They swallowed the red coloring matter, a waste product which had been hard to get rid of, and used this as a medium for carrying fresh oxygen from the lungs to the muscles, so when the creature took to living on land it was able to make full use of the free air it found there.

Many such cases of partnership for mutual benefit are known to biologists, who call the arrangement "symbiosis." Certain sea-worms operate a system closely corresponding to this hypothetical scheme. Being devoid of chlorophyll, the green coloring matter of plants, they have no way of manufacturing sugary foods for themselves. But after they are infected with the small green cells of certain algae the needs of both are satisfied. The green guests prepare carbohydrates by aid of the sunshine and in turn live on the protein products of their hosts.

But if the green plant cells fail to keep up the food supply the animal gets hungry and digests the vegetable invaders, although this means sui-

cide. Something of this sort happens in the animal body, when the red blood corpuscles dissolve and disappear faster than they can be replaced, "pernicious anemia" the doctors call it. But the person who shows such ingratitude to the uninvited guests that have become such useful servants is sure to suffer for it.

BLOOD RELATIONS IN PLANT FAMILIES

PLANTS have no blood, yet a German botanist has found it possible to use their juices to determine their real relationships just as comparative tests on the blood of animals show which are nearest of kin. He has shown by this method of serum diagnosis that, for example, the common milkwort displays affinity with the heather, bittersweet and horse-chestnut families; the bear-berry with the heather, bittersweet, milkwort and grape families.

What the test actually shows is merely that the proteins of these plants are similar in composition, but from this an actual family kinship, coming from a common ancestry, may be reasonably inferred. Hitherto, botanists have had no way of ascertaining the family connections of plants, and so they have classified plants according to their external forms and features, such as the number of the petals, the shape of the leaves, and the like. But this is an uncertain system since plants of recent species may develop close resemblances in appearance and structure when grown under similar climatic conditions. The new chemical method of classification by composition is likely to lead to safer conclusions.

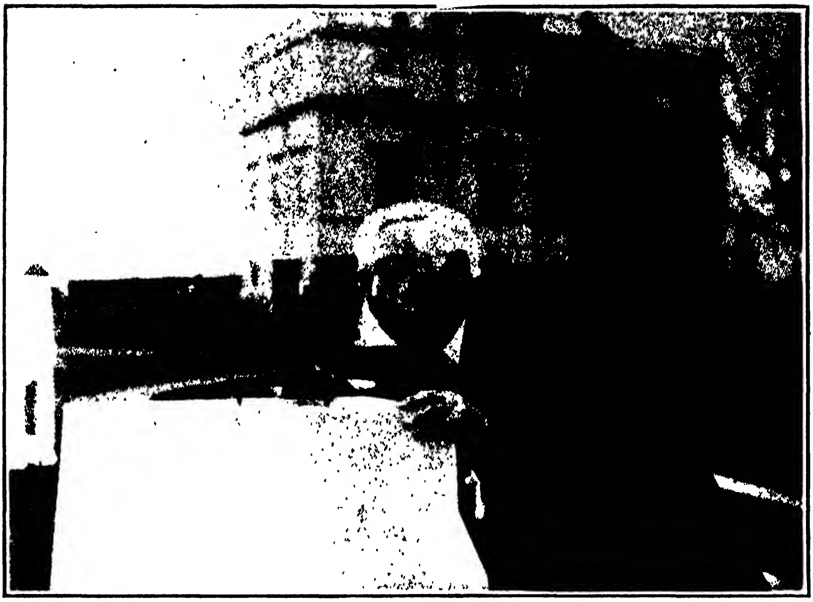
Using the serum test on animals it has been found that the blood of man corresponds more closely to that of the large tailless apes of the Old World than to the smaller tailed monkeys of the New World, while the blood of other animals differs decidedly from human blood.

PICTURE TELEGRAPHY

WHENEVER an author writes a romance of Utopian life some centuries in the future he introduces as one of the marvelous inventions of that period an instrument for seeing what is going on at a distance. Usually it is modeled after the telephone with a disk in which one can see mirrored the scene at the other end of the wire. I do not remember that any of these novelists of the twenty-first century and after have dared to discard the wire, which shows how difficult it is nowadays for the imagination to get ahead of the facts. Already we hear that wireless pictures and wireless movies will be added to the wireless telephone.

But even though long-distance photography is slow to enter into broadcasting, it will be a great thing for illustrated journalism. News comes now by wire and the pictures follow by slow freight, arriving usually a week or so after people have lost interest in the event. This delay places too much of a strain on the editor's conscience. He is sometimes unable to resist the temptation to put a stock cut to a new use or to touch up a photograph.

When Father Gapon led his procession to their death in St. Petersburg on Bloody Sunday in the first Russian revolution the American papers came out with half a dozen different portraits of him, all typical Russian revolutionists; any one of them might have looked like him, but un-



Henry Miller's News Picture Service, Inc.

DR. CHARLES CHREE

WHO WILL RETIRE SHORTLY AFTER THIRTY-TWO YEARS SERVICE AS CURATOR OF THE KEW OBSERVATORY, LONDON

fortunately none of them did. When San Francisco was burning, the most enterprising of the New York papers published a photograph of the city in flames with very natural looking smoke rolling up from it. Unfortunately the staff artist who adapted it neglected to erase the date of the copyright, which was several years before the catastrophe. During the great war the press photographers were able to produce from their stock rooms the portrait of any general whose name was cabled over. We saw pictures of the tanks and Fokkers as soon as we heard of them, though these did not look much like those that appeared later. Doubtless the early designs were abandoned.

Such accidents have a tendency to impair the implicity of the confidence which the dear reader should have in his favorite periodical. Besides, the moral character and future prospects of an editor deserve consideration. But perhaps this new machine, like all the others, will bring with it more powerful and insidious temptations. "God made man upright, but they have sought out many inventions."

THE SCIENTIFIC MONTHLY

NOVEMBER, 1925

RADIO TALKS ON SCIENCE[1]

THE ATOM

By Dr. PAUL D. FOOTE

BUREAU OF STANDARDS, DEPARTMENT OF COMMERCE

Good evening, radio listeners. Every one of you, on some bright starry evening, has stood with awe and wonder gazing at the grandeur of the celestial bodies, these countless numbers of worlds, the distances of which from our own earth are almost beyond comprehension. Each star is undoubtedly the sun in a solar system about which planets revolve, and upon some of which possibly life and intelligence exist.

Even more wonderful, however, are the miniature planetary systems of the atoms, the infinitesimal building blocks entering into the construction of every material substance. We know the sizes of these atoms, even though they are so small that the figures expressing their dimensions mean little to the average individual.

A molecule is larger than an atom. A molecule of water, for example, contains two atoms of hydrogen and one atom of oxygen. Let me illustrate how many molecules are contained in a tumblerful of water. Suppose we could label every molecule in the tumbler for future identification. We then pour the glass of water into the ocean and wait until all the water on the earth is thoroughly mixed. After this, the tumbler is refilled from the nearest hydrant. How many of the original molecules do you suppose would be found in this second glass of water? The surprising answer is two thousand. If figures can convey an impression of the size of an atom, let me

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of Mr. W. E. Tisdale.

point out that in one pound of copper there are forty-three million million million million atoms—that is, the figure forty-three followed by twenty-four ciphers.

In spite of the minute size, it is possible to weigh an individual atom with an accuracy far greater than that used by your grocer in selling sugar. Although an atom is very much smaller than the most minute particle of matter which can be seen under a microscope, yet we possess means for counting individual atoms, and we are able to determine the number in any piece of metal or matter with a precision greater than that possible in enumerating the population of a large city.

Although an atom is so extremely small, still it is an involved mechanical system in itself, consisting of a minute, complicated sun about which a certain number of planets revolve. In the atomic planetary system, the planets are all exactly alike and are negative charges of electricity called electrons. These electrons are identical with those emitted by the glowing filament in the vacuum tubes of your radio receiving set. By direct experiment we can measure the charge on a single electron, the mass of an electron, and are able to determine with accuracy the total number of electron planets in any piece of matter. The sun in the atomic planetary system is a highly concentrated positive charge of electricity, its total charge, expressed in terms of the electronic charge as a unit, being equal to the number of planetary electrons present. For example, a single atom of copper contains a sun with a positive charge of twenty-nine units surrounded by twenty-nine electron planets. In the atom of hydrogen we have a sun with one unit of positive charge about which a single electron revolves. An atom of gold has seventy-nine electrons and the most complicated atom, uranium, has ninety-two electron planets. Our own solar system consisting of the sun and eight planets resembles, in a very rough way, an atom of oxygen.

Very peculiar things may happen to the revolving planetary electrons. Two or more atoms may approach so closely together that their planetary systems interlock, thereby forming a molecule or chemical compound. A meteor, for example, another electron, may penetrate into the atomic system and collide with one of the planets so vigorously as to eject the planet completely from the system. Or the meteor may eject one of the planets a small distance out into a new orbit. The rearrangements following disturbances of this kind are manifested by the emission of radiation. If one of the inner planets is disturbed, X-rays are emitted. Disturbance of an outer planet, corresponding to Neptune in our solar system, gives rise to light or heat radiations.

We have seen that an element is characterized by a sun possessing a definite charge of from one to ninety-two units of positive electricity, surrounded by planetary electrons, some of which may be comparatively easily removed or disturbed. An atom of radium has a sun with eighty-eight positive charges and eighty-eight revolving electrons. Two of these planets are readily removed in chemical reactions, such as the formation of radium chloride. The atom, however, is still radium. That is, the real difference between any two elements is not the number of planetary electrons, but the charge on the sun about which these planets revolve. Now the sun in an atomic system, contrary to our own solar system, is a very complicated affair. In fact, the atomic sun itself is a planetary system consisting of closely packed positive and negative charges. If some of these component parts of the sun are ejected, the atom is transmuted into a new element. Such transformations are taking place spontaneously in nature. Radium is transmuted into a gas which in turn becomes a new element, a solid. Uranium is slowly turning into radium, and radium eventually becomes ordinary lead. Some forty different alchemical transmutations occur spontaneously among the radioactive elements—all occasioned by changes in the minute atomic sun.

It has been possible within the past two years to transmute certain elements artificially in the laboratory by processes where the atomic sun may be disintegrated. For example, phosphorus has been transmuted into silicon and hydrogen; aluminium has been transmuted into magnesium and hydrogen, and many elements, such as boron, nitrogen, fluorine and others, have been transmuted artificially. In fact, we undoubtedly know how to transmute any element whatever, but at present are limited in many cases by the difficulty in constructing the apparatus necessary for such experiments. There is no reason why gold may not be made from mercury; just as wonderful transmutations already have been effected.

So far these artificial transmutations of the elements have been very inefficient. The cost of producing gold from mercury by the present methods suggested would be immeasurably greater than the value of the gold. The only interest in modern alchemy, in its present state of development, is purely scientific. However, there are possibilities, perhaps mere idle dreams of the scientists, that some of these transmutations may eventually prove of value to the welfare of humanity. There is plenty of power stored in these minute planetary systems—the problem is to get it out efficiently. If the hydrogen in only six teaspoonsful of water could be transmuted into helium, energy should be liberated sufficient to propel the battleship *California* across the Atlantic Ocean. If the secret

of this transmutation be discovered, we need have little concern for the present rapid exploitation of our oil and coal fields.

We, at the Bureau of Standards of the Department of Commerce, however, are not investigating the atom with the hope of realizing such astounding possibilities. It is necessary better to understand the atom and the electron for more modest and more immediate purposes. We have in this country entire industries, the functioning of which is dependent upon the caprices of a quantity of electricity so minute as an electron. Long-distance telephonic communication, with or without wires, the X-ray or Coolidge tube used for medical purposes, the production of illumination such as the arc lamp and the more efficient operation of industrial processes involving photochemical synthesis and decomposition, photo and photographic chemistry, electrochemistry, the chemistry of gaseous reactions—all these industrial processes are such that real progress, both in the art and in protective safety devices, is conditioned by our knowledge of the changes which may take place in the interior of an atom.

CARVING THE SCIENTIFIC POSSUM

By Professor ERNEST MERRITT

CORNELL UNIVERSITY

THE title of this talk was suggested, in a manner which may not be at once obvious, by an old song that was popular during my boyhood. I do not intend to sing it, for the musical side of the radio program is well taken care of without my assistance. In fact, except for the central motif of the song, I have entirely forgotten it. There were twenty or thirty verses, each ending with the refrain, "Carve that possum," and all devoted first to a eulogy of roasted possum and then to a description of the proper method of preparing it. The process of preparation was described at length, with detailed instructions for each step. Certainly no one could listen to that song—much less sing it—without being convinced that roast possum was a most desirable and appetizing dish.

And there was a logical sequence in the thing that impressed me greatly. In giving his instructions the writer did not plunge into the middle of things, but started at the beginning and went on step by step to the sweet and succulent end. The beginning appealed to my youthful common sense—and appeals even now to my more mature common sense—as a very proper one. If condensed into form suitable for a cook book it would have read "First, *catch* your possum!"

One could not help realizing that unless this first piece of advice was followed the rest of the song might as well be left unsung and there would be no occasion to "carve that possum." To my mind that was the motif of the song.

Now it is pretty evident that this same common-sense advice to first catch your possum may properly be applied to a number of other things, sometimes even more important than possums. My intention is to show how it applies to science.

No one in these days needs to be reminded of the importance in modern life of applied science. Try to imagine what our civilization would be like if we had no steam engines, no electric light or telephone or telegraph, none of the metals that the chemists have shown us how to obtain, or the dyes or medicines that they are able to prepare, none of the serums and antitoxins that help to prevent and to cure disease. All these things and thousands of others—practically everything of a material kind that makes our life different from that of the dark ages—are the result of applying scientific knoweldge.

It is applied science that makes our modern civilization possible. But there can be no applied science until there is science to apply. That is the point which it seems to me needs stressing. First catch your possum. *Then* cook him and prepare him for the table. Finally carve him and give every one his fair share.

Strange to say, it is only in recent years that the importance of this essential first step has been realized in this country. We have had many skilled cooks to prepare and serve the scientific possum, but relatively few hunters to bring in the raw meat. Fortunately the situation is changing. But many still fail to realize how essential is the foundation of pure science upon which the inventor or the applied scientist must build.

Let me give a very obvious illustration: Many of us can remember the time when incandescent lamps with a filament of tungsten took the place of lamps with a carbon filament. The change resulted in a much better lamp and a saving of hundreds of millions of dollars. The development of the tungsten filament lamp is one of the triumphs of applied science.

But if some chemist had not already discovered tungsten and shown how to get it out of its ore this particular triumph would not have been possible. First catch your possum. The hunter who first detected this particular possum was a German. The one who brought down the game was a Spaniard; and chemists all over the world had been studying his peculiarities for over a hundred years before the cooks began to prepare him for the table. So far as I know every great advance in applied science has a similar history.

No cook, however skilful, can prepare a meal unless he has at hand the raw materials. No inventor, however ingenious, can make an invention without using the materials and the knowledge which pure science has provided for him.

Besides furnishing the raw materials there is another way in which scientific knowledge helps the inventor: it shows him the *possibility* of practical applications. Suppose that some Roman emperor had felt the need of rapid communication with his army or with some distant province and had called upon the engineers and inventors of his day to find a method. They would probably have suggested runners like the original Marathon runner, or men on swift horses, or perhaps a series of men sending messages by smoke signals or flags from one mountain top to another. Would any one have thought of sending messages by means of wires? Would any one have dreamed of such a thing as the emperor's talking to his people as President Coolidge spoke to the people of America on March fourth? It isn't until we know that there is such an animal as a possum that we can even dream of using him to prepare a meal.

If we study the history of great inventions we always run across another fact that is common to all, but which at first seems so strange that we can hardly believe that it is always true: namely, that the most essential part of the scientific foundation on which the inventor builds was developed without reference to practical applications and with no thought of the use to which it is later put. When Scheele discovered tungsten he was not hunting for a means of improving the incandescent lamp and reducing the cost of electric lighting. In his day there was no incandescent lamp to improve. Artificial light was furnished by candles and by lamps burning sperm oil. The discoverer of tungsten had not the remotest idea what the practical uses of the new metal would be. He did not know whether it had any practical use; and in fact it wasn't until a hundred years later that any practical use was found. We do not know any more than Scheele did what the future uses of tungsten may be.

In most cases practical application does not wait quite so long after scientific discovery as in the case of tungsten. The electric telegraph was made possible by Oersted's discovery of the magnetic effect of the current and followed this discovery in about forty years. Radio telegraphy was made possible by Hertz's discovery of electric waves in 1890. Nine years later, in 1899, Marconi had sent messages across the British channel and twelve years later, in 1902, across the Atlantic. The first use of radium for the treatment of cancer followed its discovery by about three years. The

use of X-rays in surgery came almost immediately after the rays were discovered. I have a very vivid recollection of using X-rays only a few months after their discovery in the attempt to locate a safety pin which a squirming and indignant baby was supposed to have swallowed. We can feel pretty certain nowadays that a big scientific discovery will be followed by practical applications within a few years.

But even if the applications do not come soon enough to benefit us they will surely be of use to our children. We don't know what the applications will be, but we can feel absolutely sure that they are on the way.

The scientific worker of course gets a good deal of satisfaction out of the conviction that every scientific discovery is sure to be ultimately of practical value. But I very much doubt whether that is his chief stimulus to scientific work. I have compared the scientific discoverer to the hunter who finds the possum and kills him so that the cook may have his raw material. Of course many men earn their living by hunting. But unless they enjoy hunting for its own sake they are not likely to be very successful, and will probably choose some other occupation. There are plenty of jobs that pay better than hunting possum and are not such hard work. The same thing is true with the job of hunting scientific possum.

I imagine that the real stimulus to scientific discovery is simply curiosity. We may dignify it by the name of scientific curiosity if you like, but it isn't essentially different from plain everyday curiosity. Take, for example, the early history of electricity. If we trace back any of our applications of electricity, from electroplating to radio, we finally come to a man in ancient Greece who noticed that when he rubbed a piece of amber on his toga it would attract things. Now what was it that led him to study this curious behavior and so to launch the science of electricity? Was he thinking of dynamos and silver-plated spoons and long distance telephony? Not by any means. He was simply interested and amused by something which probably seemed to him of very little importance, but which nevertheless aroused his curiosity. For two thousand years the science of electricity was kept alive and slowly progressed because of this same sort of scientific curiosity. *Now* we are coming to realize that curiosity of that kind pays. It doesn't pay the scientific discoverer. I never heard of a discoverer becoming wealthy. But scientific curiosity pays the world as a whole. It may be that it was curiosity that killed the cat; but for human beings it is a very desirable quality. Without it material progress would slow up and finally stop. So when your little boy uses his new knife to remove the polish from the grand piano or goes after

an alarm clock with a hammer in order to find out what is inside, it may seem wise to guide his activity into other channels, but don't chide him too severely. When this curiosity of his gets its growth you may find that he is a scientist.

Now I have rambled on for nearly the whole of my allotted time and have hardly made one serious remark. But there really is a purpose to this talk, namely, to point out that so far as their bearing on material progress is concerned pure science and applied science stand or fall together. Pure science is of no practical use until it is applied. But without pure science applications are impossible.

If we wish to continue roast possum as a part of our regular diet, even after the supply now on the market is used up, we must make sure that the scientific possum hunters keep on the job. Let us give them reasonably comfortable tents to live in, good weapons to hunt with, and above all plenty of ammunition; and let us recognize that they, like the waiters and the cooks, are doing their part toward making the feast a success.

METEORS

By Dr. GEORGE P. MERRILL

DEPARTMENT OF GEOLOGY, U. S. NATIONAL MUSEUM

A FEW months ago, on a bright, cloudless day in midsummer, a funeral was being held in the churchyard of a little town in the west. In the midst of the services there came from the sky four terrific explosions followed by shrill, whistling sounds and sounds like those of an airplane, and smokepuffs were seen high in the air; then a quantity of rock fragments, the largest weighing nearly forty pounds, came to the ground and buried themselves in the earth. Naturally many of the people were much frightened at such a bombardment taking place at the time and under the conditions mentioned, and some were disposed to regard it with a considerable degree of superstition. In the light of history, however, the matter has become commonplace, not that such incidents occur with great frequency, but that during the past centuries of observation a great many records have accumulated and we now know that masses of stone or metal may fall from space. Where they come from we are not prepared to say definitely, but of what they are we are now fully cognizant, and we call them meteorites.

Now before going further I want to call attention to what to my mind is a very interesting feature of meteorite falls and which

to the public at large is little appreciated. While we were taught as school children that the weight of the atmosphere is such as to exercise a pressure of approximately fifteen pounds to each square inch of surface, it was not very firmly impressed upon us that this pressure might be enormously increased by the motion of either the air or that of a body moving in the air, itself quiet. We are brought to a realization of it, however, when we stagger against a March gale of wind, or ride on the front seat of a rapidly moving automobile. We guard against it by windshields and goggles and we now know that it is only speed and incidental air pressure that keeps an airplane afloat. But these speeds are tame compared with that of a meteor which often comes into our atmosphere traveling at a rate of from twenty-five to fifty miles a second, or fifty to one hundred times as fast as the swiftest projectile from our most powerful pieces of ordnance. Picture to yourself, then, a solid body plunging downward into our atmosphere under such conditions. What happens? There will be brought to bear upon it a pressure of not less than 10,000 pounds per square inch, and the meteorite, if of friable stone, is crushed to fragments, as when a boy throws a snowball against a brick wall. If the meteorite is of iron it may withstand the pressure, but in either case it catches fire and may be completely consumed. Out of the millions of meteors that come into our atmosphere every day a very large proportion of them are burned up. It is these that form the shooting stars that may frequently be seen on clear, cloudless nights stealing silently across a section of the sky and disappearing. It is only when of sufficient size to escape destruction that they come crashing to earth in the manner I have described. And this gives us opportunity to consider for a moment what might happen to our earth were it not for its protective armor plate of atmosphere. It has been calculated that any iron meteorite must lose 90 per cent. of its substance by being burned away in its passage, while its speed is checked from whole miles a second to that of a body falling merely from the attraction of gravity. Think then of the bombardment to which we would be subjected were there no atmosphere to protect us and the meteorites were ten times as heavy.

As I have stated we are as yet by no means sure where the meteorites come from. The most satisfactory theory would seem to be that they are fragments of comets which have gone to pieces.

It is of interest to review the opinions of some of the earlier workers. A German by name of Chladni more than a hundred years ago advanced the idea that they were but the remains of cosmic matter employed in the formation of worlds. He considered

comets, falling stars, meteoric fire balls and meteorites as all of similar origin and elementary matter.

Wilhelm Olbers, another of the early workers, thought for a time to have demonstrated that they were ejected from volcanoes on the moon. Later he changed his views and thought their source to have been a small planet that once occupied a position between Mars and Jupiter but which has now gone to pieces, leaving in its place four large fragments or planetoids and a myriad of smaller ones which are slowly drifting back to earth in the form of meteorites. Still others have conceived of the moon having been thrown off from the earth in its youthful days and carrying with it a quantity of smaller fragments, which, drifting about in eccentric orbits, are gradually being gathered in once more. Still others look upon them as products of disintegration of a planet blown to pieces by some unexplained and unknown internal force. None of the many suggestions have proved satisfactory in all their detail.

Astronomers tell us that in the far reaches of space beyond our solar system are clouds which obscure the more distant stars, as nearer stars are obscured by thin clouds of vapor. What is the nature of these clouds is wholly speculative. That they are not of water vapor seems certain. May we not with a fair degree of assurance assume that they are composed of fragmental matter like the ejectamenta of a modern volcano and that in time they will be gathered in as meteoric material by neighboring planets. When we consider the aftermath of sun glows due to volcanic dust after the eruption of Krakatoa this should not be a difficult conception and it is an interesting thought, at least, that in the dark, wholly lightless portions of the sky there may to-day be worlds in the making through the ingathering of this waste material.

Equally interesting, but perhaps even less probable, is the suggestion of one noted scientific man to the effect that to barren and newborn worlds life may be brought by wandering meteorites. The objection to this lies largely in the fact that so far as we now know our meteorites are wholly of volcanic matter and not likely to contain life of any kind or in its simplest form.

That the meteorites that come to earth are directly connected with the periodic meteor showers there seems little doubt, but it is a singular fact that our most impressive falls do not occur contemporaneously with them. This is doubtless due to the small size of the individual in the shower, which astronomers say may be even smaller than a pea.

Of all the meteors that come into our atmosphere but a small portion survive to reach the earth, as I have already noted, and a still smaller number are found and preserved—not over three or

four a year. So far as we have information but two fell within the limits of the United States in 1924. I have made calculations based on reported weights and find that the total weight of all known falls, since records began to be kept, was but a little short of 200 tons. Those then who would have our earth built up of meteoric matter must, unless the rate of accumulation was vastly greater in the past, allow a very long time for its consummation, a period indeed running up into many billions of years.

Of course but a very small proportion of all the meteoric matter that comes to earth is ever found. But one fourth of the earth's surface is land, and only a portion of this so inhabited as to make finds probable, even were the falls seen. But about 250 have thus far been reported for the whole United States and portions of less than a thousand are preserved in all the museums of the world. There is seemingly no rule whatever for their distribution. Naturally a falling stone would be seen by more people in a thickly inhabited region, but if it fell on rocky soil or one covered with swampy lands or brush the chances would be against its actually being found. China is certainly densely enough populated and many falls have been reported, but there are no records of finds.

There seems to be something singularly elusive in the fall of a meteorite. It does not strike the ground where the observer thinks it is going to, but perhaps miles away. I have had occasion to notice this very many times. People will tell me they saw one fall and they send me a piece of it which usually proves not to be meteoric at all. One man sent me a stone that he was sure he saw fall and it was so hot he said it set fire to the grass. But what he sent me was a piece of quartzite belonging to a very ancient geological period that had been carried to the point where he found it frozen in the ice of the glacial epoch many thousands of years ago.

Robert Frost writes a poem about hunting meteorites. "Never tell me," he says, "that not one stone of all, that slip from heaven at night, and softly fall, has been picked up with stones to form a wall." And then he goes on: "From following walls I never lift my eye, except at night to places in the sky where showers of chartered meteors let fly."

I am afraid Mr. Frost is wasting his time. Searching for meteorites would be even more discouraging than that for the needle in a haystack, for in the latter case one supposedly has grounds for believing the needle to be there. But there is always the possibility. I know the case of a boy in a far-off state who found a queer-looking stone which proved to be meteoric. He then made a prolonged search and found several more which he sold for enough to give him quite a lift with his school expenses. I should state,

however, that these fell all at one time and the region was a dry one with little undergrowth to hide them.

As a rule meteorites, except in a dry climate, are of a very perishable nature. Not merely does the metallic part undergo a quick oxidation, but there is a minor constituent, one occurring in small, seemingly almost insignificant quantities, that makes much trouble. This is a compound of chlorine and iron which is peculiarly susceptible to oxidation, and begins "rusting," as we call it, almost immediately. Many meteoric irons are very quickly destroyed if left unprotected. For this reason probably no meteorites are found except on or near the immediate surface. If they fell in earlier times they have all been destroyed.

Of all instruments and instrumentalities for finding meteorites where not actually seen to fall the humble plow and its less humble holder have proved most fruitful. The expression "found while plowing" has become almost stereotyped through abundant repetition. In this way have been found a considerable number of the meteorites from the states of the lower Mississippi Valley. The reason is almost self-evident; it is one free from glacial drift, and the prevailing rocks of softer limestone, sandstone or shale. The plow strikes an obstruction which on examination is found to be of metal, or if of stone unlike anything in the neighborhood. Curiosity prompts the finder to take it to his home where perhaps it is put to some utilitarian purpose until some one comes along and recognizes it. Several large meteorites were found in Kansas some years ago by being struck by mowing machines and plows. It was a region of prairie soils, without stones of any kind. Hence they attracted the attention of the ranchers, who took them home and used them to hold down hay stacks and barrel covers until their true nature was discovered. In such cases the finder may himself suspect its nature and send it away for determination. I get a considerable number of such finds each year but am sorry to record that all too few prove to be meteoric.

The fascination of the study of meteorites is due in large part to the fact that they give us some clue to the nature and composition of other bodies in space. The telescope has taught us something of the size and shape of these bodies, the spectroscope something of their elemental composition, but in the fallen meteorite we can actually hold in our hand for examination and study a solid mass of rock that has come to us from unknown though outside sources. This was realized by the great naturalist Humboldt many years ago when he said: "There are only two avenues to our knowledge of the universe outside of us, one being light by the agency of which the motions of the heavenly bodies are revealed to us, while

the other consists in the masses of matter that come to our earth from the outer universe."

But what are these masses, you very likely will ask. I have already stated that they are in part of stone, in part of metal, but usually a mixture of the two. The metal is mainly iron with a smaller percentage of nickel and cobalt and traces of manganese, phosphorus, sulphur and platinum. The stony meteorites are interesting because they are all of an igneous and volcanic nature. No meteorite was ever found that consisted of limestone, marble, sandstone, shale, slate, schist or gneiss or any of the sedimentary or metamorphic types of rocks common to our earth and nothing in the nature of granite or of a fossil. They all belong to a very basic type which we call peridotite, pyroxenite or basalt and which from a geological standpoint are for the most part comparatively insignificant. And here is a very interesting and remarkable fact. So close is the resemblance between the meteorites and these terrestrial peridotites that an element found in one may safely be predicated in another though not in the same form. For instance, iron so abundant in meteorites in metallic form, though common in terrestrial rocks, rarely occurs other than as an oxide. This is on account of the abundant oxygen in our atmosphere and it teaches us that the meteorites were formed in a region where there was very little atmosphere. The world's supply of platinum and of diamonds comes from rocks of the peridotite group and traces of both have been found in meteorites. Truly, as the Frenchman Descartes wrote many years ago, "It is proper to infer that the earth and the heavens are made of one and the same matter."

HIGHWAY RESEARCH

By Professor S. S. STEINBERG

UNIVERSITY OF MARYLAND

GREAT as is our national prosperity, we have but few industries in which the total annual expenditure is more than a billion dollars. Authoritative estimates place the total expenditure for the construction and maintenance of roads and streets in the United States during 1924 as one and a half billion dollars, thus placing the highway industry in the select class of billion dollar enterprises. In view of this vast expenditure, scientific research, resulting in the more economical design, construction and maintenance of our highways, has great financial value in reducing the cost of highway transportation. When we consider that motor vehicles travel three hundred

million miles per day in the months of heaviest travel, that our annual consumption of gasoline is six hundred billion gallons and that our tire and accessory bill alone is eight hundred million dollars, we must realize that the economies that may be effected by the application of highway research result in an enormous saving both to the highway and to the vehicle owner. Experiments conducted in Iowa have shown that every dollar expended for gasoline on bad roads can be reduced to seventy cents on a good road.

One of the national agencies which is most active in stimulating highway research is the Highway Research Board of the National Research Council, of which Dean A. N. Johnson, of the University of Maryland, is chairman and Mr. C. M. Upham, state highway engineer of North Carolina, is director. This board recently held its fourth annual meeting at the National Academy of Sciences in Washington, D. C. At this meeting over three hundred representatives were present from state highway departments, universities and other organizations engaged in highway research, and much valuable information was presented regarding the economic factors pertaining to highway transportation.

A large proportion of the funds expended in the highway industry is appropriated to maintenance, as even the most scientifically constructed roads must be maintained. The continual stream of traffic passing over the highways of the country necessitates unremitting attention on the part of those to whom the highways are entrusted. For a number of years the necessity for constructing new roads and reconstructing old ones to keep pace with the enormous increase in automobile traffic shoved the matter of maintenance into the background, but in the last few years most of the states have been making intensive studies of their highway maintenance problems.

One problem that comes under the head of maintenance is snow removal. This illustrates anew the marvelous changes which have been wrought in our social and economic life by the development of the motor vehicle. Ten years ago the tremendous inconvenience and the enormous loss occasioned by blockaded highways after every heavy snowstorm were accepted by people generally with patient resignation. As the automobile, the motor bus and the motor truck came to be used in increasing numbers in moving passengers and supplies, the necessity for keeping highways open every day in the year became more and more apparent. Now in all the northern states the highway departments are removing snow on the country roads under their jurisdiction. Work of cleaning the snow on the through routes between the large cities usually begins before the snow stops falling. Most of the machines, such as tractors and

blade graders, which are used for maintenance during the summer, are called upon for snow removal in the winter.

Developments in highway traffic are so rapid that it is difficult to foretell accurately conditions over a very few years in the future. Using the available statistics for motor vehicle registration during the past years and studying its relation to the corresponding curve of population in the United States, Dean A. N. Johnson, of the University of Maryland, has reached the conclusion that there will probably be about thirty million motor vehicles on the highways in 1930. A similar study by Dean Johnson has shown that the average life of the motor vehicle is increasing from year to year. Thus the average life of an automobile bought in 1912 was about five years, whereas one bought in 1916 lasted about six and a half years. This increase in service may be attributed both to the better design of the vehicle and to the increase in the mileage of improved roads.

With the rapid development of motor vehicle transportation, need for new laws and regulations arose, and in the absence of definite information many of them were based on more or less scientific guesses. For instance, many laws regulating the maximum load that may be carried by trucks are based on total wheel load alone. They serve their purpose very well when the truck is not in motion, for a wheel at rest can exert no greater pressure than the actual weight upon it. Research conducted under the supervision of Mr. T. H. MacDonald, chief of the United States Bureau of Public Roads, has shown that the instant the wheel is set in motion a different condition develops. As the truck moves along a road, surface variation, tire roughness and other factors cause the wheels to mount vertically and on returning to the road make them capable of delivering impacts or blows equivalent to seven or eight times the actual wheel loads. In order to avoid these impacts and thus reduce the wear and tear on the motor vehicle and the highway, as well as the exhausting effect on the occupants of the vehicle, much attention is now being given by construction engineers to the degree of smoothness of the finished concrete. Instruments are being developed which will record the exact location of troublesome areas or obnoxious bumps. One state uses an apparatus which is attached to an automobile and which makes an automatic record of the deflection of the front spring. Another state uses a device mounted on sixteen wheels drawn by a truck which gives an accurate profile of the road. In order to obtain as smooth a highway surface as possible, the specifications in a number of states require that all inequalities of over one fourth inch, as shown by a ten-foot straight edge on the finished concrete pavement, must be removed.

Consideration of the gasoline tax is of special interest to the motor vehicle operator. Thirty-five states now have this form of tax, the rates ranging from one cent to three cents, with the exception of one state, which has a four-cent tax. A one-cent gasoline tax increases the cost of operating the average vehicle by one tenth of a cent per mile. On a trip from Washington to Philadelphia the tax would amount to ten cents. The trip over the Lincoln Highway from New York to San Francisco would be taxed $2.50. The motorist or truck operator is assured of a good return from the taxes he pays, since the receipts are very largely devoted to road construction and maintenance. In 1923 four fifths of the motor vehicle license revenues and more than one half of the gasoline taxes were turned over to the state highway departments for expenditure under their supervision, and a considerable portion of the remainder was expended by the counties for road purposes.

The problem of highway finance resolves itself largely into a question of the just distribution between the burden on land, or real property, and the burden on the highway user. It seems only fair that the highway user, whose demand for service is largely responsible for highway improvements, should assume an equitable share of the burden in the form of motor vehicle and gasoline taxation.

In the United States there are about three million miles of all types of roads. Of this amount about 15 per cent. are improved with some kind of surfacing and nearly all this improvement has been made within the last ten years. The mileage of the so-called earth roads, without any surface improvements, is therefore about eighty-five per cent. of the total, or two and a half million miles. In view of this enormous mileage of local roads, highway engineers are seeking a new type of surface that will serve for secondary traffic and yet be low in first cost and maintenance. Because of the small amount of traffic on the local roads, the construction of expensive surfaces, such as concrete, asphalt and brick, are not economically justified. Highways surfaced with gravel will carry five hundred to six hundred vehicles daily, but begin to show ruts when that number is exceeded. The Highway Research Board hopes that research will find a surface that will carry up to two thousand vehicles a day and will be intermediate in cost between the gravel road at $8,000 a mile and the concrete road at $35,000 a mile.

The need is felt for some method of stabilizing earth roads, particularly in wet weather, so that the local farm roads may be made to withstand the increasing demands of traffic upon them. Whether this be brought about by X-ray treatment of the soil, removal of those invisible but tangible particles known as colloids, or by heat

treatment of the earth, or by other means, is for research to determine.

In his travels, the average motorist would rather meet with an accident than with a detour. This may be due to the feeling that before he is through he may be faced with both. Highway engineers, realizing the worries incident to detouring, as well as the wear on the vehicle and the loss in time occasioned by it, are anxiously awaiting the result of researches being conducted with a view to accelerating the curing or setting period required for concrete.

This, the greatest era of prosperity in the United States, is in no small measure due to our system of highway transportation. To insure its continuance, highway engineers, enlightened by highway research, definitely commit themselves.

COMMUNISM AMONG INSECTS

By THOMAS E. SNYDER

U. S. DEPARTMENT OF AGRICULTURE

MAN'S civilization is higher than that of insect communists: man is developing, while they are standing still. Can we not build our houses so as to keep out these most undesirable citizens? In the world war of man against insects, although greatly outnumbered, man's intelligence will eventually win the battle against insect vandals.

PREHISTORIC CIVILIZATIONS

Civilization ever has been the pride of man! However, certain insects had established civilizations and social systems before the evolution of man; these civilizations of insects are geologically much older than either man himself or his boasted civilization. The "social insects" include the bees, wasps, ants and termites (or "white ants") which live in colonies, have a well-defined caste system and closely adhered-to division of labor.

THE TERMITES

The termites or "white ants" are typical of these social insects, since they display an elaborate society or communism in an old or primitive form of life, paralleling the society of the more highly specialized true ants. For termites, although ant-like in appearance, are not true ants, but a much lower form of life; they are most closely related to the cockroaches, which are, geologically, very ancient insects. Unlike the ants, termites are not terrestrial, dominant insects; they are pale in color, blind, soft-bodied and usually subterranean or, at least, secluded in habitat. They have been forced to "dig in" in order to survive, but have, in consequence, "underrun" tropical countries.

There are a few exceptions, where the termites are harvesting in habit and come above ground into the sunlight; these forms, however, are dark colored and have eyes. Normally, termites are forced to construct earth-like "shelter tubes," whenever they come above ground in search of food or water; often these tubes run up on the trunks of trees to great heights, especially on cocoanut trees in the tropics.

Ants, being terrestrial and aggressive, use their jaws, sting and formic acid spray as weapons of offense as well as for defense.

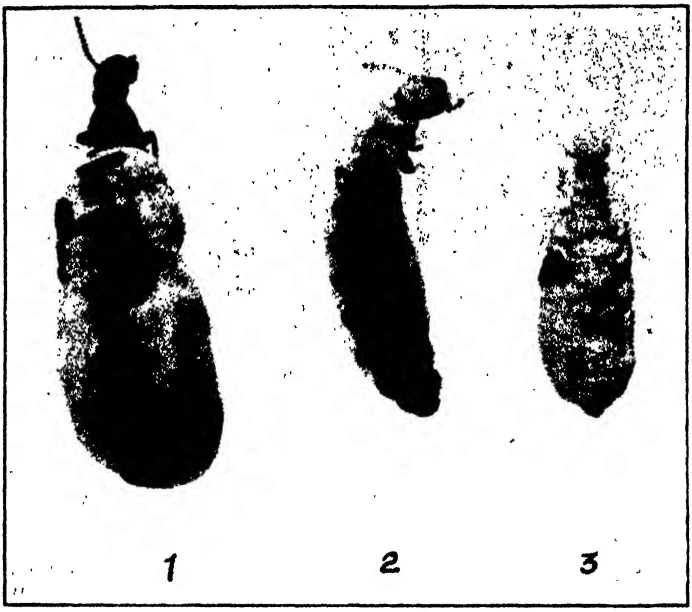


FIG. 1. THREE TYPES OF EGG-LAYING TERMITE QUEENS FOUND IN THE UNITED STATES

1, the deälated winged form; 2, the form with short wing pads; 3, the wingless form. It is useless to search for and destroy the queen; hundreds develop to take her place.

Termites have all their weapons located on the head and the jaws and repugnant frontal gland secretions are used merely for defense.

Termites are fewer in number than ants, only about fifteen hundred species, at present, being known. They are widely distributed throughout the temperate to the tropical regions of the

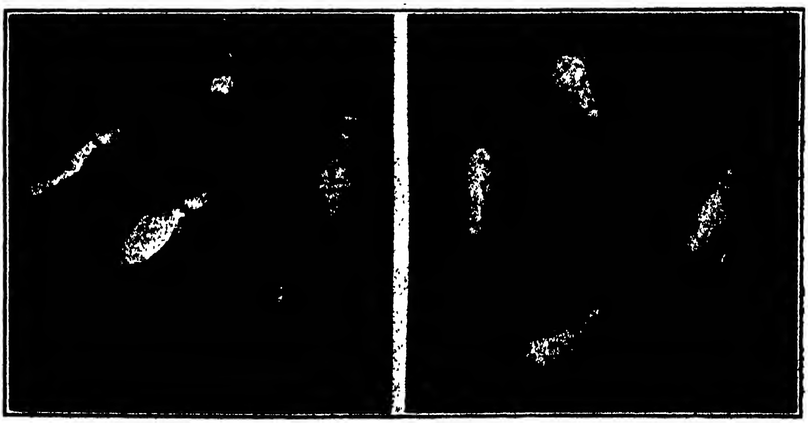


FIG. 2. Worker termites on the left; Soldier termites on the right. (Panama.)

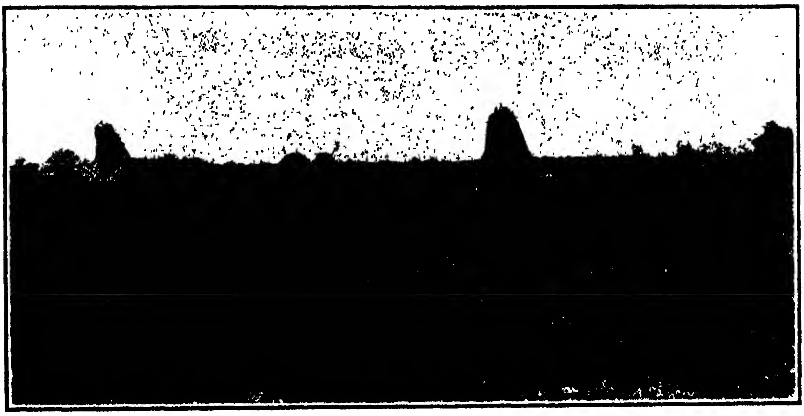


FIG. 3. HIGH MOUND NESTS OF TERMITES IN PANAMA

world, but reach the height of their development and abundance in the tropics. There are forty species in the United States, distributed from Maine (even from Ontario, Canada) to Florida; through the Central West, south of the Great Lakes; in the Rocky Mountain region and on the Pacific Coast.

THE CASTE SYSTEM

Colonies of termites consist of "kings and queens"—the parent reproductive adults—"workers" and "soldiers," all of several types, of diverse and often very odd forms. The ancestral termite was represented by a single winged form (males and females),

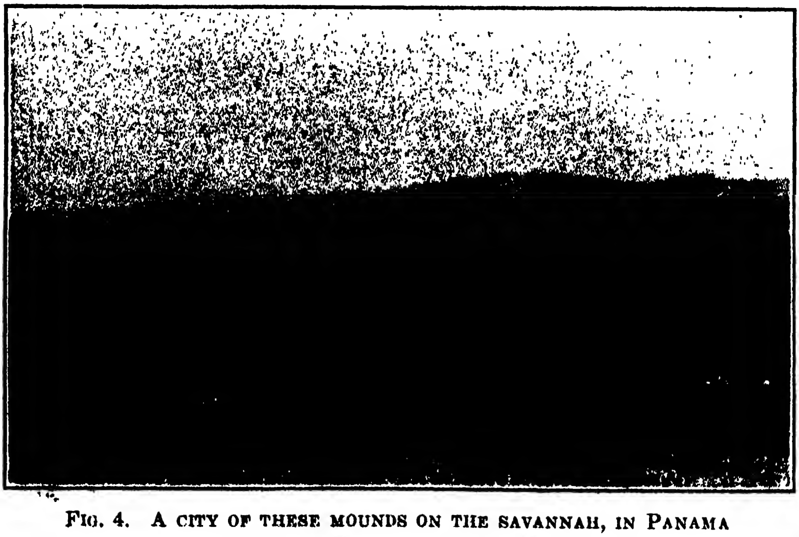


FIG. 4. A CITY OF THESE MOUNDS ON THE SAVANNAH, IN PANAMA
(Photos 3 and 4 by J. Zetek.)

which mated and reared other sexual males and females. Gradually, through the ages, after gregarious life, colony life developed and other forms or castes have appeared.

Some of these forms are other types of sexual adults, with short wing pads or entirely wingless; others are sterile workers and soldiers, incapable of reproduction, but especially fitted for certain duties in colony life.

The workers care for and feed the young, the reproductive forms and the soldiers; the soldiers defend the colony when invaded by the greatest enemy of termites, the true ants. For this rôle of defense, saw-toothed jaws or mandibles were utilized by the most primitive termites. Later, a special gland on the front of the head, which exudes a sticky secretion, developed and superseded the mandibles.

Among the termites intermediate between the primitive and highly specialized forms, both mandibles and frontal gland function. This pungent secretion, which exudes either from an opening, a short tube or an elongate beak, is more effective against ants than are jaws. These gland-bearing termites, when in contact with ants, thoroughly gum them up, so that they are rendered helpless.

In other highly specialized termites, the jaws are markedly asymmetrical or very slender, elongate or twisted. Jaws of the latter type could not possibly be used for biting, but they are made use of by bringing together and flipping or snapping particles of earth at the invaders; or even flipping away the invaders themselves.

There has been progressive development, not only in the jaws and frontal gland of the soldier, but in the legs, wings and defensive armor or spines on various parts of the body of the other castes. The more highly specialized termites have lost the strong power of flight possessed by the more primitive forms.

The most primitive termites have no workers, the only sterile caste being the soldier. Whereas, more specialized termites may have two types of workers and three types of soldiers. On the other hand, among one group of the higher termites, the soldier caste is entirely lacking. Some termites live in the nests of others, where they are afforded protection; the termites with no soldiers sometimes are closely associated with termites that have "soldiers."

The Colonies or Nests

The colonies or nests of termites are constructed of earth or earth-like material, in the ground, in low or tall mounds on the ground, in carton tree nests, or within wood. They far antedated the "adobe" houses of man, his use of pressed dirt for foundations and walls of buildings and of wood for shelter. Often whole vil-

FIG. 5. A "NIGGERHEAD"
Carton termite nest in a tree. (Panama.)

lages or cities of termite nests dot the plains or prairies, as do the huts of the aborigines. These nests are hard, oriented with reference to the sun's rays and afford protection from both animal life and the elements. Termite nests in the tropics of Africa attain a high type of architectural perfection and are so constructed, utilizing shingle or ledge-like processes, as to shed rainfall—often torrential in these regions—yet at the same time permit free ventilation.

Within these nests there is an orderly and systematic arrangement of cells and galleries to house the large number of inmates. There is a special cell or "royal chamber" in which the parent reproductive forms, normally a single pair, are practically imprisoned. This chamber is usually in the most protected and inaccessible portion of the nest. From this cell galleries run to favorably located "nurseries," to which the young or nymphs are carried by the workers, for feeding, care and more rapid development in the warmer portions of the nest. These galleries, however, will not permit the passage of the old queen. She is merely a huge, highly developed, immobile and imprisoned egg-laying machine, fed and tended by the workers.

During her youth, she and her male consort struggled hard to establish a home and feed and rear the first brood of young. Later, with care and feeding by her young she grows to a proportionately enormous size, reaches the dowager stage and is more or less helpless. She loses the power to move about, the jaw muscles degenerate and she is fed by workers on an especially prepared rich diet. With the king she may live as long as twenty-five years.

If the queen dies or is lost, the old king will forego his former meritorious monogamous life and consort with a harem of young queens, with short wing pads, veritable insect "flappers." When both the queen and king die, large numbers of young queens with short wing pads and a fewer number of similar kings will replace them.

Hence, it will be seen that the termite colony is not a "feminist" society, as is the case with the bees and ants. Even with communism, there are "equal rights" for both sexes! Even the workers and soldiers are of both sexes, although they are sterile!

Other galleries lead to "fungus gardens," wherein peculiar, edible mushrooms are grown by the termites. There are exits and

FIG. 6. SECTION THROUGH TERMITE NEST TO SHOW "FUNGUS GARDENS"

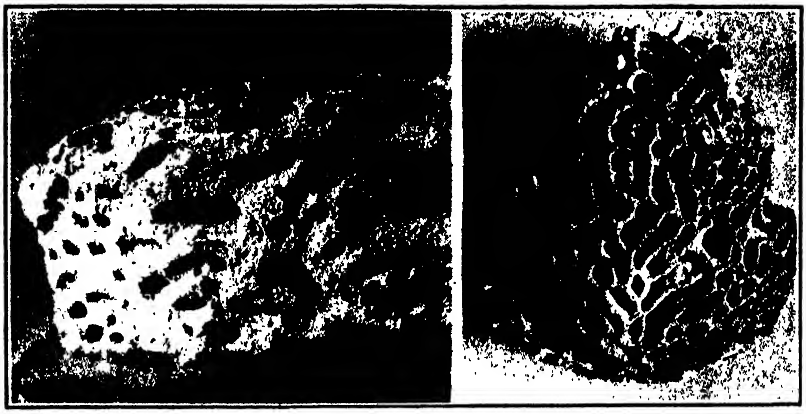


FIG. 7. TWO TYPES OF COMB FROM FUNGUS GARDENS
Showing the "cauliflower"-like fungus growth as bright, white granular bodies.

entrances well guarded by the fearsome-appearing, large-jawed soldiers.

In nests of other types, there are storage rooms for vegetation, harvested and brought into the nest by large files of foraging workers, with their ranks closely guarded by the soldiers.

Some termite nests are entirely within the wood of trees, logs or stumps; this wood serves as both food and shelter. The nests made in the wood are similar to those constructed in earth. The chief food of most termites is cellulose, which they obtain from living or dead wood and other vegetation. To digest this cellulose termites have within their intestines thousands of protozoa—low forms of life—which serve as enzymes.

FIG. 8. CLOSER VIEW OF THE CAULIFLOWERS. (Java.)
(Figs. 6, 7 and 8 photographed by D. Fairchild.)

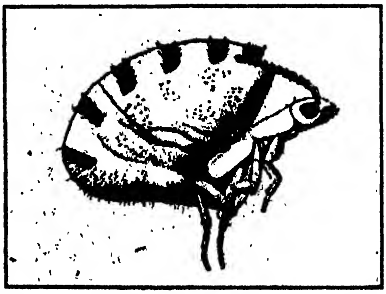


FIG. 9. A PROTECTED INSECT GUEST OF TERMITES
Which lives with the termites in a mutually beneficial rôle; the termites obtain exudate from the guest, the guest food from the termites. (After Silvestri.)

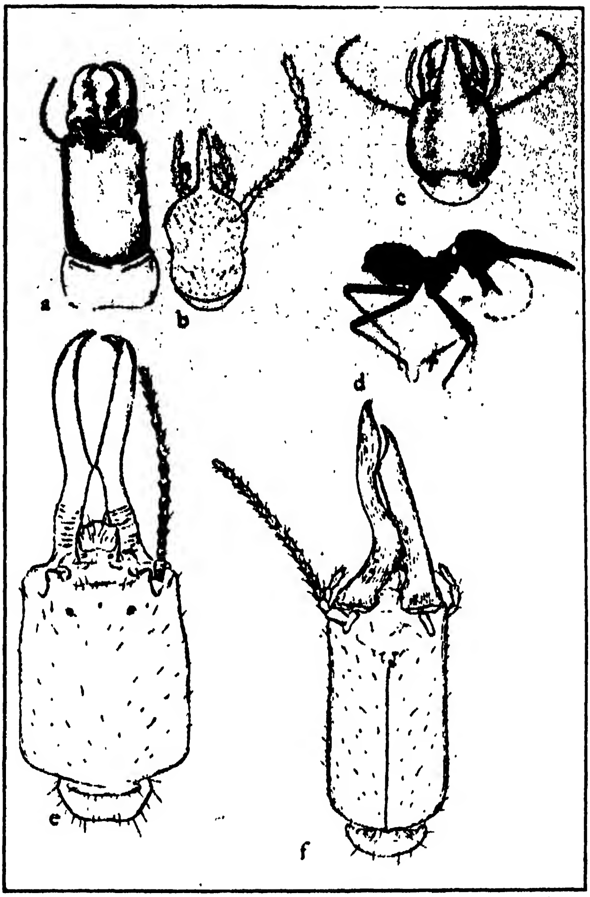


FIG. 10. HEADS OF CONTRASTING TYPES OF TERMITE SOLDIERS
(a) Soldier with saw-toothed jaws; (b) soldier with a beak which secretes a repulsing liquid; (c) soldier with a combination of jaws and beak; (d) full view of such a soldier; (e) and (f) soldiers with elongate or twisted jaws used defensively in flipping dirt.

These peculiar, odd-shaped protozoa are found only in the bodies of termites—nowhere else in nature. Termites whose food is not cellulose, but mushrooms or other special diets, obtained from the "workers" or protected "insects guests," do not contain protozoa. These guests of termites are degenerate but highly specialized forms which serve as "ant cows."

Occasionally termites vary their vegetable diet with a meal on a feeble or disabled fellow-communist. All their instincts of care and feeding of young are based on selfish impulses. They obtain body secretions or exudate in return!

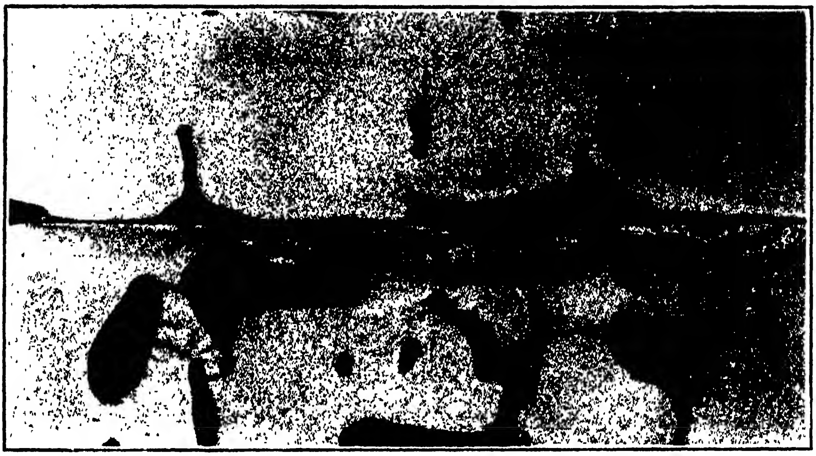


FIG. 11. DAMAGE BY TERMITES
Damage to reels of imported French cigarette paper stored in a factory at New Orleans, La.

COMMUNISM AND ITS LIMITATIONS

Nevertheless, while man and his civilization are comparatively young and there have been ebbs and flows in development, there has been consistent, if not continued, progress. Termites, on the other hand, after having reached certain states of body and community development, have made no further progress. Of course termites, as well as other insects, can not reason and are merely guided by hereditary instincts and tropisms—hunger, sex and fear being the principal impulses. Their progress was by evolutionary development, as was man's, but man, with reasoning powers and individual initiative, has been able to surpass all other forms of animal life. Granting this, man will lose his birthright of freedom if he ever submits to the limitations of communism. Let him "go to the ant or termite" and take heed! Russia has both types of insects within her vast domain!

THE SWARM

Interest is always attracted by unusual flights of any form of animal life, whether birds or the less conspicuous insects. In the tropics, especially, there is almost an element of magic attendant upon a termite "swarm." After a rain, apertures are opened in the ground or "ant mounds," and suddenly the air is alive with fluttering, winged hordes, which emerge from these exits. After this flight, which may last for several hours, the holes are closed from within by the workers and all trace of life disappears, even as suddenly as it had appeared.

This is the annual colonizing flight of the sexual adults; these are impelled to swarm to establish new colonies. It is not a "nuptial flight," as is the case with bees and ants. Only after losing their wings do males and females mate and form new homes in wood or in the earth. When this flight occurs in a building in the United States, it should serve as a danger signal to the householder that the woodwork of the buildings is infested by termites. Such swarms occur at least once each year, in the spring or autumn.

ECONOMIC IMPORTANCE OF TERMITE COMMUNISTS

Like other communists, termites have a great facility for destroying the property belonging to others. They do millions of dollars worth of damage annually. Such damage is greatest in the tropics, but even in temperate regions, their ravages entail losses of thousands of dollars. With the felling and clearing of forested land, termites attack the buildings, crops and other works of man. Serious damage is done to any untreated timber which is in contact with the ground, such as telephone poles, wooden bridges, windmill

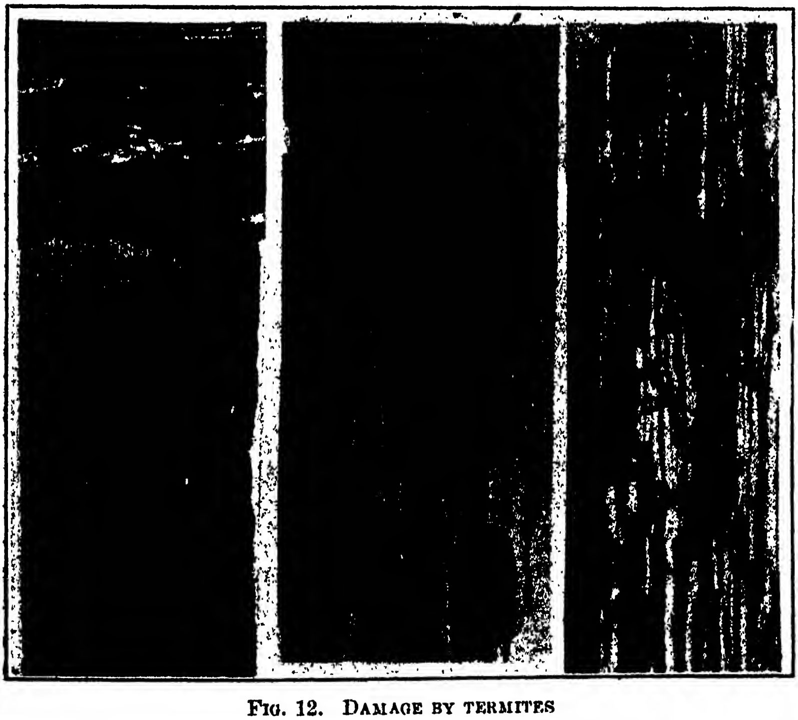


FIG. 12. DAMAGE BY TERMITES
On the left, California redwood beams, in a building on the Pacific Coast, eaten through by termites native to the United States. In the center, cottonwood beam, in "adobe" house in Arizona, burrowed by termites. On the right, pine flooring, in Iowa, honeycombed by termites.

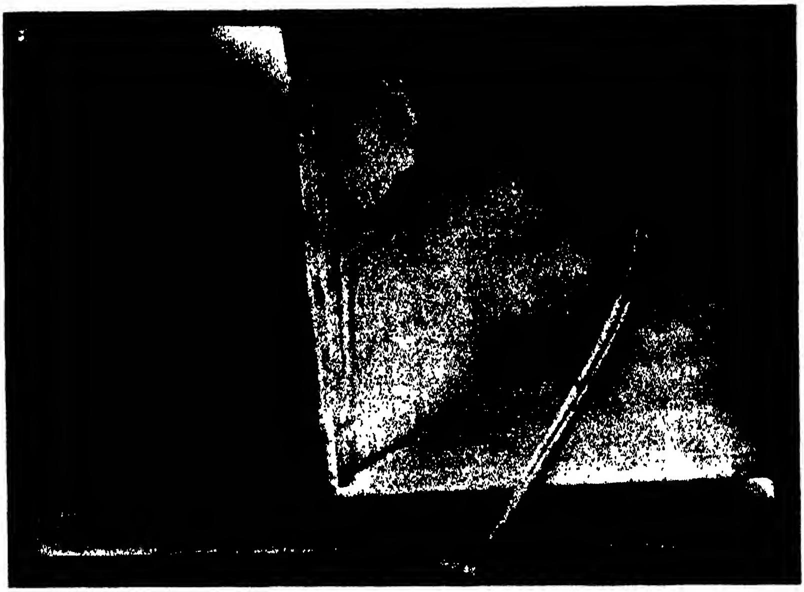


FIG. 13. BOOK RUINED BY TERMITES AT WASHINGTON, D. C.
Communists destroy books, especially those dealing with law and order.

towers, silos, fencing, and all types of buildings. Forest, shade and fruit trees, as well as living crops, are injured.

Perhaps the most serious losses in the United States are caused by termites to the woodwork of buildings and material stored therein. Such damage could be very easily prevented by slight modifications of city-building regulations; untreated wood must be insulated from contact with the ground. Keep timber, political and wooden, away from dirt!

REGULATIONS AND CONTROL

The United States Department of Agriculture receives many requests each year as to how to get rid of these "flying ants" or termites in buildings. Most of this damage is due to improper construction. Termites enter the woodwork of the buildings because, somewhere, there is untreated wood in contact with the ground.

Recently, the Department of Agriculture has been advocating a few slight modifications of the building regulations of various cities, in efforts to prevent attack by these insects. These rules are: No untreated wood should be laid on or in the earth, and untreated beams should have at least an inch of concrete between them and the earth. Where it is desired to put wood in direct contact with the earth, it should first be impregnated with coal tar creosote. If

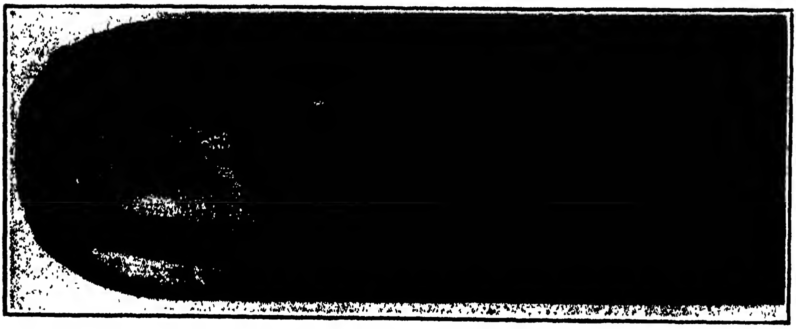
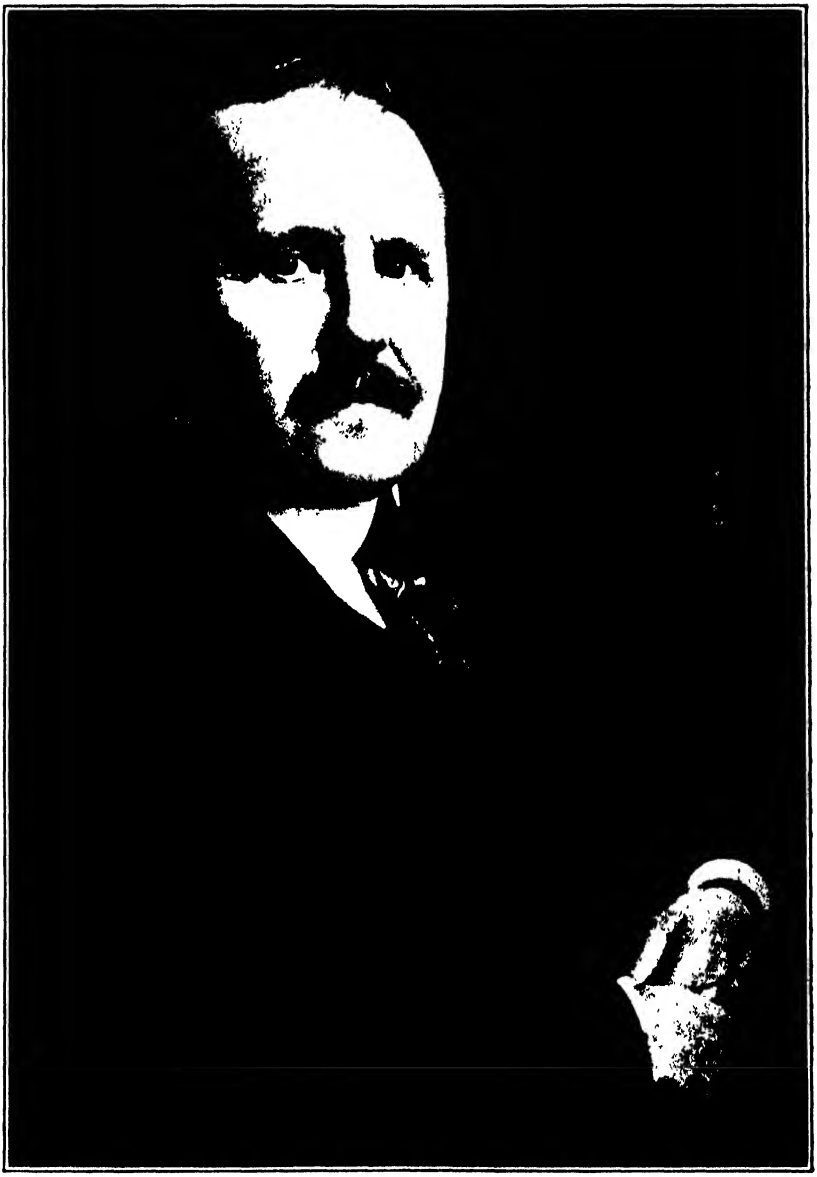


FIG. 14. BASEBALL BAT DAMAGED BY TERMITES AT WASHINGTON, D. C.

this is not practical, there should be foundations of concrete or stone. No lime mortar should be used in brick work in foundations of buildings, since termites are able to penetrate lime mortar after a few years' service. Such brick work, either on or extending below the surface of the ground, should be faced and capped with concrete at least one inch thick.

Termites are not like ants, which can be killed by insecticides or fumigation; they must be prevented from getting into the building from the ground, through their hidden burrows in untreated woodwork.

It is a great hardship for a householder, on a moderate salary, to be forced to spend several hundred dollars a few years after purchasing a building because of damage by termites. The fault is in the construction, and the building regulations should be such as to avoid this damage, so that the householder should not have to pay. By insisting on complete insulation of all untreated woodwork from the ground, insurance against attack by termites can be secured.



WILLIAM ALBERT LOCY

WILLIAM ALBERT LOCY

ZOOLOGIST AND HISTORIAN OF BIOLOGICAL SCIENCE

By Professor C. E. THARALDSEN
NORTHWESTERN UNIVERSITY

WILLIAM A. LOCY was a man who was distinguished alike for the diversity and importance of his original contributions to knowledge, his historical work and his influence on men of science as well as the laymen: one whose supreme gift was the ability to see with an intelligent and interpretive mind and whose published observations reflect this quality in their high level of scientific achievement. His death, October 9, 1924, terminated a long and rich career of noble and unflagging devotion to science which secured a harvest of abundance. It is an honor to the various learned societies to have numbered Dr. Locy among their members. It is an honor to Northwestern University to have felt his influence for so many years. We here express our reverence for the man, and our admiration for the scholar. It remains our part to keep alive the tradition of truth-loving, of scientific devotion and of perfect modesty which is our legacy from W. A. Locy.

A descendant of Dutch ancestors who emigrated from Holland in 1651, William A. Locy was born in Troy, Michigan, in 1857. Graduated from the University of Michigan in 1881, he remained with his Alma Mater one year as a graduate student in zoology, receiving his master's degree from that institution in 1884. He pursued advanced work at Harvard in 1884 and 1885, holding a fellowship under Mark. The year 1891 was spent at the University of Berlin. In 1894 he was awarded an honorary fellowship at the University of Chicago, where under Whitman in 1895 he received his doctorate. He also spent several summers at the Marine Biological Stations on both the east and the west coasts as well as one season at the Naples station. In 1906 he was awarded the honorary degree of doctor of science from his Alma Mater, the University of Michigan.

Besides being a member of the honorary and scientific fraternities of Phi Beta Kappa and Sigma Xi, Dr. Locy was an active member of the American Anatomical Association, the American Society of Naturalists, the American Zoological Society, of which he was president in 1915, the American Association for the Advancement of Science, the History of Science Section of the American Associa-

tion for the Advancement of Science, of which he was one of the founders and its first vice-president, the Microscopical Society of Illinois and the Illinois Academy of Science.

After four years of apprentice work in secondary schools, Dr. Locy entered upon his academic career in 1887 when he accepted the professorship of biology and later of animal morphology at Lake Forest University, a position he held for eight years. In 1896 he succeeded Professor E. G. Conklin as director of the Zoological Laboratories of Northwestern University and continued there as an active teacher and producer up to the day of his death—a period of twenty-eight years. During his life, Dr. Locy produced fifty-six papers—several of which were landmarks in their respective fields. Three books, all on the history of biology, also were credited to his pen, the last of which was sent to the publishers but a few days before his death. During his connection with Northwestern University, fifty-four advanced degrees were awarded to research students doing work under his supervision.

A mere enumeration of cold facts does not give us a complete conception of Locy, the man, the teacher, the zoologist and the historian. Conklin said, "I honored him for his unselfish devotion to his chosen work and his loyalty to his associates." His manner was courteous, his spirit gentle, his tastes simple. He lived the life of a scholar whose highest ambition was to know the truth and make it known to others. He possessed a strong and upright personality of Spartan simplicity and was an untiring man of science to whom work was a pleasure of creative power. Sincerity, accuracy and transparent honesty characterized all his deeds. He had the courage of his convictions and the independence of one who had early learned to think and investigate for himself; his good sense exerted a most wholesome influence on educational theory and practice; his cheerful and straightforward friendliness endeared him to all who knew him. There was little self-seeking in his nature. He was unselfish and sincere with all men, blessed with a broad charity that was not critical of small things. He sought no positions of honor, but faithfully discharged every duty that was his to perform.

He was not a recluse, but kept in energetic touch with the social and intellectual life of the community, nor could he be comprehended in the scientist or the educator, for he enjoyed enviable intimacy with fine letters in both verse and prose. He was abreast of current events, a student of art and a lover of music. Above all he was not a nihilist, but a constructive philosopher, who going from effect to cause found real rest for his philosophical faith in a primal cause.

In scanning his life it would seem as though he had been inspired to fulfil a mission of diversified good, for his major achievements fall into three distinct fields of endeavor, that of teacher, zoologist and historian.

Locy took up his life occupation of teaching with other preparation than that of the patient student and promising scholar, in that he put into it the power of a great personality which helped to inspire and determine the life ideals of many young men who came into contact with him. Perhaps his greatest delight and satisfaction was in his work which brought him into immediate relation with active and earnest students, many of whom are already reflecting credit upon the profession whose testimonials assign their inspiration with affectionate veneration to this master teacher.

Dr. Locy was interesting as a lecturer and knew how to arouse enthusiasm and to inspire the student to independent thought. He had the faculty of clear and forceful statement, being logical rather than rhetorical, convincing rather than persuasive.

He had a catholic spirit that sought the truth in everything and rejoiced in finding and was always enthusiastic for any genuine effort to extend the borders of human knowledge. His scholarship was comprehensive, accurate and exacting. Although he spent much time with his advanced students and his own researches, he never neglected the elementary student, but religiously held to the idea that the course in general zoology was most fundamental, as here the foundations are established for future inspiration and work. Under his direction, this course grew in popularity and became one of the largest classes in the university from which more than the average number of students followed up the general course with more advanced work.

Locy always emphasized the importance of what might be termed old-fashioned zoology. He held that in the complicated maze of specialization in the various modern branches of the subject the student was apt to lose perspective of the field as a whole and that the foundations of all zoological knowledge could only be established through a thorough training in comparative morphology. It was always his purpose to systematize the development of zoology and present it as a harmonious whole by bringing out and correlating the salient features that have been established through the course of this development. Comparative morphology, therefore, formed the background of the zoological curriculum, a thorough training on which he insisted before permitting the student to pursue more special branches.

He was a pioneer in this country in utilizing the method now widely recognized of presenting the zoological courses on a historical

background, emphasizing the fact that we know most vividly that which we know in its origins. Throughout his twenty-eight years at Northwestern this was always an integral part of his courses, and he wrote articles urging the modification of our pedagogy to include the teaching of science in its evolution as a more successful educational method.

His scientific papers and addresses from the very first showed his enthusiastic interest in scientific work and his love and appreciation of zoological research. He was always hospitable to newly discovered truths and thus continued to be a student and investigator to the end of his days. Without a doubt, his researches, although many, would have been greater if confined to narrower lines, but I am inclined to think that he was the better teacher because of the wider range of his field. Sincerity, accuracy and honesty characterized all his work. Those who had the opportunity to know his papers collectively know how strikingly manifest was his devotion to the furtherance of zoological knowledge. His writings everywhere reflect the spirit of a leader of thought. His scientific contributions evidence great power of observation, extreme care and active scientific imagination, as well as a strong sense of the fundamental. He therefore engaged in no petty researches and the few that he published included several landmarks in their respective fields.

Locy's first paper of consequence was on the embryology of the spider. Here he made the first comprehensive attempt at an analysis of its early embryological development. To this day, this work stands as one of the two authorities on this subject. He was also the first to explain substantially the development of the spider eye.

Following this work came a series of twelve papers, embryological and neurological in character, dealing with the brain, special sense organs and cranial nerves of vertebrates. His studies of the embryonic neuromeres of the fore- and mid-brain of fishes stand in the forefront of investigation on neural metamerism and in the center of the controversy that still continues on this subject. His observations on the accessory optic vesicles in the chick embryo threw new light on transitory organs of the neural tube and gave support to the hypothesis that the vertebrate eyes are segmental. His studies of the nervus terminalis in elasmobranchs, while not contributing an entirely original discovery of this addition to the classical roster of cranial nerves, was nevertheless contributed so early and was so thorough as to dominate and become the standard of all later investigations. In his investigations on the fifth and sixth aortic arches in birds and mammals, Locy settled the discussion as to the existence of the sixth aortic arch and identified defi-

nitely the origin of the pulmonary artery. Through investigations of the embryology of the bird lung, he clarified the recognized morphological inadequacy and incomplete knowledge on this important organ.

For a man whose major time was devoted to teaching, he contributed in unusual measure toward zoological research and to the history of biological science.

Reminiscing over his student days when zoology was in its infancy, Locy made the statement that zoology was purely descriptive. He said:

> I craved for a broader view of the salient features of biological progress to see what it was all about. I asked for bread and they gave me stones. Nothing but my own deep-seated interest in natural history impelled me on to the point where I was able to gain that perspective for myself. It was this experience which made me realize the importance of the historical aspect of the science, and it was here that I conceived the idea and developed the ambition to be able some day to develop an account of the rise and progress of biological thought.

Although his first published papers on the history of biology did not appear until later in his life, this phase of his activity has undoubtedly become his most noteworthy achievement and that by which he will be remembered longest. All his life he had been a student of history, but this interest was first developed into tangible form when under the influence of Whitman, in 1894–95, he was encouraged to give it serious attention. This interest resulted in his first historical paper in 1901 on Malpighi, Swammerdam and Leeuwenhoek, a paper which received very enthusiastic reception. From this time on, two different interests are clearly marked in Locy's work; one, the detailed morphological investigations in the laboratory; the other, the historical researches into the musty volumes of the past. At first the former held the balance of his interest, but gradually as time went on his historical researches focussed his attention. The productive period of his life may be divided roughly into two periods: the first from 1884 to 1901, dominated by his detailed morphological researches, and the second from 1901 to 1924, characterized by his historical work on the rise of biology.

The historical phase of Locy's interest covers three lines of endeavor. First of these was his individual papers published on certain definite periods, topics and men of biological importance; the second was his three books on the history of biology and zoology, covering the field in general; and the third was characterized by his efforts to promote interest in research on the history of science and its importance as an educational need.

Individual papers on special phases of the history of zoology and biology, such as "Malpighi, Swammerdam and Leeuwenhoek," "Von Baer, and the rise of embryology," and "Anatomical illustrations before Vesalius" were clear-cut, scientific analyses of facts gleaned from the original sources which cleared up and brought under a common point of view many disputed points.

In 1908, he made his first attempt to bring together the broader features of biological progress by the publication of "Biology and Its Makers." This volume has perhaps been more widely read than most historic-scientific books. It is an untechnical account of the rise and progress of biology written around the lives of its great leaders. It represents the first comprehensive attempt in America to correlate, condense and popularize the various branches of biology. It is inevitable that biologists in special fields should find many imperfections in such a general work, but the chief purpose of the author to indicate the sources of biological ideas and the main currents along which they have advanced was accomplished in an admirable manner and the work has created an epoch in the advancement of biological history. It has filled the gap which he himself felt during his college days, and from my own experience, I know that it has been the direct inspirational cause that has induced many a young man to enter the field of zoological research as a life work. To the layman it has given a readable and much needed humanizing account of the important part that biology has played in intellectual progress.

Ten years later followed a more condensed volume entitled "The Main Currents of Zoology." As the title indicates, this is a historical treatise confined entirely to the field of zoology. Here Locy pictures the broader developmental features of zoology as a unified science and not merely as accretions of knowledge concerning animals. He draws a vivid picture of its importance as a subject of general education and also outlines the outstanding biological advances of the nineteenth century.

The effect that these two books have had on the teaching of zoology as well as being general cultural contributions can not be overestimated. Aside from the fact that Dr. Locy was a pioneer in this field in America, it is interesting to note that the general zoology, botany and biology text-books everywhere have adopted the historical method of presentation to a greater or less degree since the publication of these volumes, and a number of them have made direct use of the material which was made available by his work.

During the last few years of his life Dr. Locy had been conducting extensive researches with the view of building up a com-

prehensive survey of the growth of our knowledge of all organic nature from the earliest foundations down to the present time. This contribution was intended to be a two-volume treatise, but the author lived only to complete the first volume which was sent to the publishers shortly before his death. Although this volume is complete in itself and will be a monumental contribution befitting this great man, the scientific world has lost much through his untimely death.

His efforts directed towards the promotion of research in the history of science in general are nowhere better illustrated than in the organization of this society of eminent men whose primary aim is the cause he so valiantly championed. He was one of the members of the committee appointed by the permanent secretary of the American Association relative to the History of Science Section. The results achieved by this committee were to a great extent the efforts of Professor Locy and it was through his efforts that the policy and organization of this section was largely determined. He always took an active part on programs and committees. His efforts were recognized in that he was elected its first vice-president. His loyalty and devotion to the history of science movement to create an independent section was not rewarded during his lifetime.

At this close range there is difficulty as well as danger in attempting to define Locy's position in the history of the development of science. The history of science is an attempt to clarify man's relationship to nature as contrasted with the philosophical history which deals with the ultimate reality. During the middle ages science was a part of theology. Theologians defined scientific thought in the interest of a supernatural interpretation of the universe. The progress of science was parallel with a continuous movement to secularize it, to make it the property of the layman and to remove it from the bonds of prejudicial interpretation. Locy's historical contributions have been a record of the part that the biologists played in this movement. Of all phases of this intellectual transition, science undoubtedly has been the greatest secularizing agency. Among the sciences, biology probably played the foremost rôle, for it was more closely connected with man's social evolution, and the biological principle of evolution contributed as much as any other factor in bringing about the radical changes of thought with regard to man's relation to the universe. Locy's contributions therefore cut through the very essence of European thought during this period. Within the last decade, there has not been a general history produced which does not devote at least a chapter to the history of science and the part it has played in in-

tellectual and social progress. In this connection we find the contributions of W. A. Locy always mentioned as among the foremost biological sources.

Most historians do not have the scientific training to evaluate scientific facts, and most scientists lack the historical perspective to comprehend the relation of the development of scientific thought to the general intellectual development. Locy seemed to possess both qualities and as a pioneer in the biological phase of this movement in America he has contributed much. The fact that his contributions were translated into the German would indicate that his work was not local in influence.

Locy's contribution to the development of the history of biological sciences, depicting the struggle and final triumph of this important branch of scientific thought, is only a part of the larger story of human progress in general; yet it is an important part and represents an earnest attempt on the part of a man of science to seek out the broader avenues of intellectual development in the biological field and to make them known to others. The results of his own labors are the most fitting monument that can be erected to his memory.

NEW LIGHT ON THE PHYSICAL DATA OF LANGUAGE

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Egocentric Conceptions in Science

The advancement of science may be defined as the progressive enfranchisement of the human mind from the tyranny of an egocentric consciousness. The royal prerogative of the spirit to hold itself superior to the phenomena of matter is undoubtedly necessary to a well-ordered intellectual "state of man"; but successive delimitations of the exercise of the prerogative have proved indispensable to the efficient coordination of those functions of mind which determine the immediate and practical knowledge that we call science.

Astronomy made little progress until once for all it shook off the tyranny of astrology and abandoned the belief that the movements of the heavenly bodies were "secret influences" commenting upon human activities. So with chemistry when it gave over alchemy and efforts to discover a means of transmuting gross and ignoble substances into the "noble metal" of gold. These enfranchisements were violent and revolutionary. That of physics has been more gradual and apparently is not yet quite complete. A few physicists still seem to expect the discovery of a source of energy that will redeem man from the first curse which makes him unhappy in this vale of tears, and one of them has even provided for him when he leaves it a Valhalla which he may enter without the trouble of being "born again."

While such vagaries of individuals are not, of course, chargeable to the subject itself, they nevertheless show how easy it is to frame a twentieth-century knowledge of physical phenomena in the egocentric categories of the Renaissance. And it is especially easy for the college student of physics to do this because much of his cultural training involves egocentric categories, and many subtle confusions between what is physical and what is psychological still cling to the skirts of physical theory.

The phenomena of light, thanks largely to spectroscopy and photography, and consequent connections with chemistry, are now analyzable into mathematical relations more or less independent of visual sensation. The phenomena of electricity, owing to their intimate connection with the chemistry of matter and to the fact

that they have few obvious relations to cardinal modes of sensation, are comparatively free from psychological distinctions, and our knowledge of them, such as it is, is almost wholly mathematical.

Their Prevalence in Acoustics

But our fundamental definitions of sound are still largely psychological and egocentric, and our fundamental categories for its phenomena, *viz.*, "pitch," "loudness" and "quality," are essentially psychological distinctions, each of them being a tacit reference to certain reactions of the human nervous system as they affect auditory sensation.

While this fact has not invalidated the work of the physicist, it has forced upon him the more or less unnecessary burden of familiarizing himself with data which are not physical but psychological. It is significant that much of the essential progress in the field of acoustics has been due to physicists who have been familiar with the development of music, and that the field of speech sound, of whose development the physicist as a rule knows little, has until recently received almost no illumination from physical investigations.

Their Effect upon the Study of Language

Moreover, this confusion between physics and psychology is largely responsible for the crude and erroneous egocentric conceptions of language which beset our cultural education and render nugatory most of our practical training in this important function of consciousness.

The physicist is often really thinking psychology when he thinks he is thinking physics, and the psychologist is often thinking physics (and that, too, of a somewhat amateur brand) when he thinks he is thinking psychology. And when the mere philologist, who must needs make love to the assistance of both these gentlemen, seeks the whys and wherefores of the speech-sound phenomena with which he must deal as recorded facts, he is buffeted back and forth between psycho-physics and physico-psychology to no purpose but the irritation of all parties concerned.

The reason for these conditions lies in the fact that until recently experimentation in this field has been largely dependent upon the human ear for a means of recording and analyzing the phenomena in question.

Recent Progress in the Technique of Sound Measurement

But the past ten years has seen the development of sound-measuring mechanisms that are much more delicate than the human

ear and are more or less independent of its limitations. Take, for instance, the phenomena of so-called "beat tones." It is a well-known fact that when two air-wave trains, each producing the effect of a tone, combine under certain circumstances, three tones are heard, the two corresponding to the two air-wave trains and a third which is different from each. Professor D. C. Miller with his Phonodeik has shown experimentally that this beat-tone has no physical existence, but is a ghostly creation of the auditory mechanism, a psychological hallucination common to all normal minds and having much to do with our appreciation of music.

Much of this recent progress has been due to telephony and the transmission of speech and musical sound by radio, mechanical operations which have made these questions matters of practical engineering.

We are thus upon the edge of a new development of physical science which is of vast consequence to the science of language.

One of the first fruits of these new investigations will undoubtedly be a new phonetics built upon definite physical data to take the place of the ancient speculative system founded upon data which are uncertain and arbitrary. It is the chief purpose of this paper to forecast the development of this new system along the lines which recent physical investigations into the nature of speech sound are already fast determining.

The Arbitrary Categories of Medieval Phonetics

Attempts to determine the constants of speech sound are by no means new. The Romans of the classical period were more concerned with the rhetorical applications of language than they were with its essential nature. Like many of us moderns, they took speech for granted and skill in its use as a more or less divine gift, and displayed little curiosity about the nature of its phenomena. Cicero, for example, observing that the Latin of his day is surprisingly constant in respect to vowel length and pitch distinctions, "even among the unlearned who know nothing of grammar," concludes that these things are *communibus infixa sensibus*, and uses the fact as evidence of intuitive perceptions mysteriously implanted in the human soul.[1]

Later, however, when Rome was flooded with foreign immigrants whose *communibus infixa sensibus* belonged to quite a different category from Cicero's, and the uniformity of Latin pronunciation no longer prevailed, especially among the intellectual classes developing the new foreign religion of Christianity, grammarians began

[1] Cicero, De Orat., 3, 195; Orator, LI, 173. It is the context of these passages that is significant.

to concern themselves with phonetic standards. The late imperial and early medieval Latin grammarians thus developed theories of phonetics whose main purpose was to harmonize the two essentially different systems of Latin phonology—the classic system with its tone-length and pitch differentiation of syllable units, and the popular system of the later empire with an energy and stress differentiation of syllable units.[3] The student of philology will find in Martianus Capella's "de Nuptiis Philologiae et Mercurii" (c. 400 A.D.; first printed in 1499) the phonetics which ultimately prevailed to become the foundation of the Renaissance teaching of the language.

Since the written forms of the corresponding syllable units were practically the same in classic and medieval Latin phonology, this phonetics was built up on the supposed constant values of the letters of the Roman alphabet—its vowels *a, e, i, o, u,* together with their digraph combinations, and its consonants, divided into various sub-categories according to the ingenuity of the grammarian.

Renaissance Conceptions of Language

The egocentric conception of language as a divinely given or humanly invented means of *representing* ideas by more or less unchanging written symbols was the only possible basis of philology in the fifteenth century. For the actual phonology of spoken Latin was then a uniform stress phonology, and the phonologies of the chief vernacular languages of Europe which used the Roman alphabet were in substantial accord with it; no one could have suspected the natural laws of development which had been at work for fifteen hundred years to change the fabric of Latin phonology.

The Romance languages, unchecked by literary form and rule, and removed from the restraining social influences of the Capital, had developed so spontaneously and rapidly out of the new stress Latin that their likenesses to their parent had been completely obliterated. The only literary evidence of change lay in the obvious

[3] Many of them were Christians who were familiar with the old quantitative pronunciation and were anxious not only to justify their own stress pronunciation but also to claim for poetry the *psalmi* and new rhythmic *hymni* rapidly developing in the church services. They resorted to various expedients to do this. A common theory was that poetry must be read with a certain *plasma* or *modulatio* through which something is added to a short vowel to make it long—most of their divagations were due to an unconscious lengthening of acute short vowels (Atilius, Diomedes, *passim*—the practice itself is adverted to as early as Quintilian's time, cp. *Inst.* ix. 4. 84.). Another is the naïve explanation that the term "long" is relative, "just as one says that all Germans are tall when as a matter of fact one knows that many Germans are of short stature" (Marius Victorinus, "de Mensura Long. et Brev. Syllabarum," Keil. vi, 39).

inconsistency between the rules of the quantitative classic prosody and the actual phonology of the prose Latin of the Humanists.

But grammarians, whose authority was "*super regem,*" had already prepared the ground upon which to reconcile the obvious discrepancy in their tacit assumption that the language of poetry was in some way divinely different from the language of prose. The former, as Beda and Aelfric tell us, depended upon a quantity which conformed to the dictates of human reason (*ratio*), the latter upon a natural quantity which frankly obeyed normal phonetic laws (*natura*).[3]

Thus in their reading of Latin poetry the stresses of Renaissance Latin prose were shifted to conform to the rules of a quantitative classic prosody, and the resulting verses were read rhythmically, developing a proportioned irregularity that was itself considered an element of beauty, a practice and theory that still obtains in many of our universities.

Vernacular poetry was left to follow the dictates of *natura.* The ill-starred efforts of the English Humanists to import *ratio* into English failed to wean English barbarians from Shakespeare's "native wood-notes wild."[4]

This confusion between an assumed *ratio* and an actual *natura,* the product of medieval egocentric thinking, still prevails in one form or another to confuse our teaching of language, and nothing is so irritating to our modern literary criticism as an attempt to treat English poetic form from a purely historical and developmental point of view.

Nineteenth Century Phonetics

The splendid development of the scientific study of language which in the middle of the nineteenth century followed upon Grimm's discovery (1822) that the various Indo-European languages were interrelated by natural laws of phonology, enabled the philologist to escape from medieval egocentric conceptions of language phenomena.

Starting from the fundamental principle that pronunciation is quite independent of the letters of the Roman alphabet, the work of Ellis, Bell, Sweet, and Sievers gave us a system of phonetics whose

[3] This theory was common all through the Middle Ages. Aelfric in adverting to it criticises the popular pronunciation of *pater* with a short English *a* like that in "*fæder*" as detracting from the dignity of the Omnipotent ("Aelfric's Grammatik," Zupitza, Præfatio). It will be recalled that our modern "patter" comes from this pronunciation in *pater noster.*

[4] It must be borne in mind that "wild" in Elizabethan English connoted irregularity, not necessarily violence of passion. The passage is usually construed in its modern English sense.

constants were determined by experimental data interpreted in the light of the facts of language development.

The bases of their classifications were physiological; they assumed that each speech sound depended upon a fixed position of the human speech organs which gave it its peculiar quality, and that the changes which produced language development were due to genetic or racial laxities or inaccuracies in the adjustment of the speech-organ musculature necessary to produce these sounds.

This is the system of phonetics under whose rubrics modern philologists now subsume the data of phonology.

There can be no question that it marked a long step forward in the advancement of the science of language. It is fundamentally sound because physiological data do ultimately determine to a large extent the norms of speech production. It has yielded distinctions of permanent value in giving order and arrangement to the facts of language development, and has produced a system of phonetic representation which, clumsy though it be, is nevertheless independent of the spelling vagaries of particular languages. Indeed, one might justly compare the nineteenth century progress of this science made possible by Grimm's "Deutsche Grammatik" with that which was effected in biology by Darwin's "Origin of Species."

In venturing to propose a new system of phonetics, therefore, the writer would not for a moment derogate from the high excellence of the old, or from the substantial accuracy of the philological work which has been done through its agency. But no modern biologist would be content to base his investigations wholly upon the distinctions found in Darwin's "Origin of Species"; so no modern scientific student of language should be content to stand still at the point reached in Sweet's "History of English Sounds," or in Sievers's "Grundzüge der Phonetik."

The Disadvantages of the Current System with its Physiological Criteria

To the layman our present system of phonetics seems appallingly scientific because the details it presents are so multitudinous as to require a special technical training to comprehend them, and their notation is complicated by a system of mysterious signs. Ellis's "Paleotype Alphabet" contains 267 characters. A like large number are demanded for the phonetic systems of Melville Bell and Sweet. The Oxford Dictionary reduces a phonetic English notation to 98 characters, 64 vowels and 34 consonants. Of course it is possible to simplify these elaborate systems, and this is what is usually done in practice; but phoneticians are not at all agreed as to what

these simplifications should be,[5] and thus phonetic representation ceases to be uniform.

These elaborate notation systems for speech sound result from the assumption that minute differences in the possible positions of the speech organs distinguish one speech sound from another, and that these positions are constant for given speech sounds: *i.e.*, that all speakers produce a given sound in precisely the same way. But recent physiological investigations following upon the development of a more accurate technique for exploring the mouth and throat cavities during speech production are showing that our physiological assumptions do not accord with the facts[6]—in other words, that different speakers of the same sound produce it in different ways. Indeed, the relation of the volume and the ingress and egress conditions of a resonating air chamber to the quality of a sound passing through it is such a delicate physical constant, that to substantiate the assumption upon which our present system of phonetics is founded would require a constancy of size, shape, elasticity and musculature in the human vocal organs that is biologically inconceivable.

Another unscientific characteristic of our present system of phonetics is that it offers us no reasonable explanation of the facts we now know in regard to the development of language. If speech sounds depend upon a uniform anatomical consistency, why do they change, once that consistency is attained? And if they do change, why do all the multitudinous biological factors involved always change correspondingly in precisely the same direction, and to the same degrees, and at the same times, so as to keep language continuously intelligible?

These nineteenth century conceptions of speech phenomena thus present a bewildering multiplicity of distinctions with nothing but uncertain categories to coordinate them, and nothing but accident to explain them—a condition much like that of the botanical sciences a couple of generations ago.

Efforts to determine the Physical Characteristics of Speech Sound by the Study of Phonograph Records

When at the end of the nineteenth century the phonograph became a commercial device, attempts were made to learn something

[5] It is a common tendency of the phonetician to make academic distinctions—"er sieht das Gras wachsen"—and to imagine pedantic sound differentiations which are not heard in his own speech when it is unconscious, and are not normal in the speech of native educated persons who illustrate standard usage.

[6] A paper on "X-ray studies of vowel quality" read before Section L_2 at the Washington Meeting of the American Association for the Advancement of Science by Professor E. Oscar Russell demonstrated this very clearly.

of the physical nature of language by magnifying and examining phonograph records of given speech sounds. Physicists then knew that the cardinal defect of these mechanisms was that free-period vibrations due to the inertias of their moving parts—and these inertia factors were out of all proportion to the inertia of moving air—prevented them from faithfully reproducing the sounds made by the human voice. The record made was always one of air waves plus a number of sound-producing vibrations that had nothing to do with speech. But phoneticians overlooked this difficulty only to find that a careful examination of the magnified record of a given vowel tone showed that it was vastly different for different speakers, and for the same speaker at different times. Thus their attempts to simplify language study by coordinating language phenomena under modern scientific laws independent of speculation only revealed new difficulties.

At this stage of the problem the manufacturers of phonographs called in specialists in acoustic physics with a view to removing the defects of horns, the then means of increasing the force of speech vibrations to the point where they would impress a record on soft wax.

Professor D. C. Miller, of the Case School of Applied Science, was one of those who undertook this task. He first perfected an instrument for precision measurements which would record the motion of a sound wave in x- and y- coordinates with a minimum and calculable amount of distortion due to the free periods of the mechanism—the phonodeik.

Analyzing his phonodeik records into Fourier series for the energy factors of their components[7] he established experimentally Helmholtz's principle that sound quality depends upon characteristic distributions of energy among the partials of a tone through resonance, and determined by Fourier analysis the resonance characteristics of some of the commoner musical instruments. He went on to determine the resonance characteristics of eight sung or intoned English vowels and found that the constancy of their quality depended upon the fact that their characteristic resonance gave maximum energy to one or to a pair of partials whose pitch or pitches were constant for each vowel tone.

For *a* as in *father*, *aw* as in *raw*, *o* as in *no*, and *oo* as in *gloom* the maximum-energy partials were single at 910, 732, 461 and 362, respectively; for *a* in *mat*, *e* in *met*, *a* in *mate*, and *ee* in *meet* the pitch constants were double, 800 and 1840, 691 and 1953, 488 and 2461, 308 and 3100, respectively.[8]

[7] It is an elementary law of dynamics that the energy producing a vibratory motion is proportional to the square of the amplitude multiplied by the square of the frequency: $E = (nA)^2$.

[8] D. C. Miller, "The Science of Musical Sounds," The Macmillan Co., 1916.

Much subsequent investigation by physicists has substantiated Miller's conclusions as to the physical determinants of the quality of intoned vowels, but has also shown that his determinations were too rigid.[9] Miller's determinations and those of the others who confirmed them were grouped according to the traditional "vowel triangle," a kind of metaphysical diagram based upon the supposed physiological criteria of vowel tones.

The writer has shown that, though Miller's *maximum-energy partials* are constant at one or two characteristic frequencies *when a vowel is sung or intoned* at a constant pitch, its quality *when it is spoken in ordinary conversation* is determined by groups of *major-energy components* whose *mean maximal value* is constant and characteristic; and that different speakers to produce the same vowel quality will use different combinations of major-energy components according to the capabilities of their individual vocal organs; and that the same speaker may at will employ various combinations of major-energy components during the production of the successive sound-waves forming the train that the ear recognizes as characteristic of a given vowel tone, and may change its pitch and energy distribution without seriously impairing its characteristic vowel quality. Hence all those delicate shadings of stress and tone inflection which associate themselves with the logical categories and genetic feeling modes of language thinking.[10]

The Bearing of this Work upon Philology

But, one will say, what has all this theory to do with the practical study of language? Doubtless it is very interesting to the physicist, and the improved technique will furnish public lecturers with opportunities to inspire popular audiences with new thrills at the marvels of modern science; yet the fresh complications it reveals seem only to render the fundamental problems of language more hopeless.

Not at all. It has really brought them within the range of definite solutions.

A Fixed Standard of Sound Quality

So long as our standards of speech-sound quality are purely psychological they will be relative and arbitrary. If our measurements of heat variation were in terms of certain psychic effects of

[9] See a very accurate set of determinations for intoned vowels recently summarized and graphically tabulated by Dr. I. G. Crandall, of the Western Electric Company, in the *Bell System Technical Journal* for April, 1924, p. 232.

[10] See "The physical characteristics of speech sound," Bulletin No. 19, Purdue University Engineering Experiment Station, March, 1924.

molecular vibrations upon the temperature-sensation receptors of the average human being, we should really know little about heat from a physical point of view. In like manner if sound quality is measured as *organ-tone, violin-tone, flute-tone, voice-tone,* etc., with *noise* for a sort of omnibus category of sounds that the ear judges to be quite different from those it calls *tones,* our measures of sound quality will be shifting and variable. But once a physical constant of sound quality is established, a measurable scale of speech-sound quality and a scientifically exact method for the study of language become possible.

Resonance the Physical Basis of Sound Quality

Now these recent physical investigations have demonstrated that in spite of all the bewildering varieties of speech sounds, one physically measurable factor runs through them all to determine their significance for a given language, *viz.,* resonance. Without resonance our speech would be as the chirping of sparrows. Sir Richard Paget, in an elaborate series of experiments with a device of his own invention for producing speech sound by purely mechanical means, has recently demonstrated that consonants, as well as vowels, are determined by conditions of multiple resonance characteristic of each; and has actually manufactured most of them in his laboratory by synthesizing their resonance factors.[11] Thus we have at hand means of determining physically the characteristics of *all* speech sounds.

Acoustical instruments of precision have already been perfected to the point where these resonances can be accurately measured. Their effect upon the distribution of the energy in an air-wave train can thus be precisely calculated from mathematical applications of known physical laws. It only remains to establish a constant for the quantitative distributions of energy in the sounds produced by the vocal organs as determined by resonance to enable us to say just what happens in the world of matter and motion when one makes an auditory syllable gesture, so to speak. What happens to the human brain upon the receipt of the gesture from the auditory receptors (or upon the establishment of its image) is a question for the psychologist.

An Absolute Unit for Measuring Vowel Quality possible

How can such a constant be arrived at?

Starting from Helmholtz's principle that the quality of a tone

[11] See Sir R. A. S. Paget, "The nature and artificial production of consonant sounds," Proceedings of the Royal Society, A., Vol. 106, pp. 151–174; cp., also Proceedings of London Physical Society for April 15, 1924, pp. 213, 214.

is determined by an unequal distribution of energy among its partials, whose consequent varying loudnesses the hearing mechanism fuses with the loudness of the fundamental, it is obvious that if the fundamental and partials of a given speech tone were all equally loud the tone would have no quality—merely loudness with indistinguishable pitch.[12]

Since the successive frequencies of the partials of such a tone are integral multiples of the frequency of the fundamental, we have known frequency factors of their energies; and since the energies of its partials are always a constant, the successive amplitudes must stand in the ratio of $1, \frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \ldots$.[13]

As the writer has pointed out elsewhere,[14] to take the total energy of any speech-sound-producing wave and redistribute it in terms of such an assumed quality norm of the same fundamental frequency is a problem of elementary mathematics. Moreover, there can be only one such norm corresponding to a given sound wave. Since each amplitude of our assumed norm is known, by measuring the successive amplitudes of the components of any given speech tone against the corresponding no-quality amplitudes we can determine the energy ratios of its excess components. And since the frequencies corresponding to these energy ratios are in both cases multiples of the same fundamental frequency, we can derive mathematically the frequency of that single component which would represent the mean energy of the excess components, whatever their number or frequencies. This we call our Quality Constant, Q, because, as Miller has shown, it is constant for any given tone quality. This Q, from the way it has been derived, will be *the root-mean-square, i.e., the square root of the mean square, of the frequencies of the excess components weighted proportionately to their respective energies.*

Now the writer has shown that a spoken vowel, as distinct from a sung or intoned vowel, is the effect of an a-periodic sound-wave train of some 10 to 25 waves. But he assumes that the successive individual waves of such a train may be taken as constant for very brief intervals if the change in their form is gradual, and thus

[12] It is of course impossible to produce such a tone on account of the inertia of matter, and the ear could not hear it without disturbances due to imaginary beat tones. If it could exist, its psychic effect on the human auditory-sensation receptors would be analogous to that of white light on the visual-sensation receptors. The contrary effect of pure pitch results from a single tone without partials, a condition which can be approximated by a tuning fork with corresponding resonance sufficient to kill the audible partials.

[13] A curve of the successive amplitudes of such a tone drawn to rectangular coordinates of amplitude and frequency is a rectangular hyperbola.

[14] *Op. cit.*, pp. 39 ff.

determines their constants as a progressive series within characteristic limits. He finds that the mean value of these successive quality constants of a spoken vowel tone of his own voice corresponds substantially with Miller's fixed determination for the same vowel when intoned, arrived at in quite a different way. The psychological reason for this correspondence probably lies in the fact that the clangs of the spoken vowel change so rapidly in a wave-train whose maximum duration is only about $\frac{1}{8}$ of a second that their successive clang qualities produce a single pitch-loudness impression proportionate to the mean of the excess energies of the successive waves. A single wave, therefore, whose clang quality was that of this mean, would, if repeated periodically, produce the same impression.[15] Similarly the changes in the loudness and the pitch of a fusion of spoken vowel clangs are not analyzed into separate sensations but are fused in an impression of constant, increasing or decreasing pitch.

Our Quality Constant is thus a constant energy-frequency ratio based upon Helmholtz's principle of tone-quality, as demonstrated by Professor Miller for intoned and sung vowels, and extended to apply to spoken vowels. It enables us to measure clang quality in terms proportionate to the energy producing the clang impression, and is independent of physiological criteria. For any given quality-producing sound wave Q is the frequency of the single simple sine wave whose excess energy represents the mean excess energy of the major components; and if this single maximum component were substituted for the major components of the system the same clang-quality would result; Q is therefore the theoretical maximum-frequency constant measuring any given clang quality, no matter what the combination of components producing it may be.

The Vowel Tone Spectrum

An application of this method to the spoken vowel tones of English determines for each a series of successive quality constants varying within definite limits; and when these bands of variation are set down as an increasing numerical series, they reveal a succession of quality ranges like those of a color spectrum. This sound

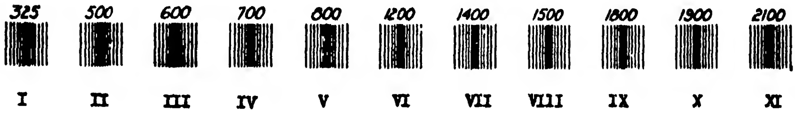
[15] A clang is the auditory impression made by a tone combined with its overtones: the impression is like a simple sensation, and is produced by the simultaneous fusion of the various tone sensations, which lose their individuality in the process. A simultaneous combination of clangs, however, produces a different impression: for in this latter case each clang being a fusion of its *own* components preserves its clang individuality in the combination. (See Wundt, "Lectures on Human Animal Psychology," Creighton-Titchener Trans., p. 73 ff.) We should therefore expect the similar condition assumed above for a rapidly successive fusion of clangs.

spectrum bears a relation to the sound-producing motions of the air similar to that which the color spectrum bears to the light-producing motions of the ether: the qualities of the one, like the hues of the other, are determined by the frequency-energy ratios of the vibrations producing them.

Our simple English vowel tones, ignoring their multitudinous spellings, may be set down in the following table:

I. *boot, two, rule, wound, tune* (Am.)
II. *book, good, poor, full, wolf*
III. *cone, road, dough, sew, trow*
IV. *sung, month, fir, earth, rough*
V. *hawk, squash, trough, all, bond, water*
VI. *father, bar, mark, grass* (British), *water* (Middle West)
VII. *mast, bat, man, laugh* (Am.), *aunt* (Am.)
VIII. *meant, said, net, bury, friend*
IX. *sail, say, prey, weight, make*
X. *it, pin, been* (Am.), *peer, sieve, syrup*
XI. *yield, seed, receive, people, machine*

Their clang-quality spectrum is as follows—the energy-frequency figures are provisional:



Our English diphthongs are combinations of clangs separated by more than one intervening band. Our English long vowels, *ō, ē, u, i,* slide from one band into a neighboring band with greatly diminished energy.

Now it will be found that the vowels systems of the various Indo-European languages are made up of selections from this spectrum, variously combined or modified.[16] English, however, adequately represents a full complement of these tones. Thus among its other superiorities—and it has so many that the writer has long maintained that English is the most perfect language in the world—the vowel system of our language is the most scientifically complete yet developed by man.

Indeed, there is much good sense in Sir Richard Paget's contention that if we would only give over our efforts to construct an international language and devote our energies to improving our own tongue, English would naturally become a medium of international communication because of its inherent fitness for such a

[16] In some European languages, however, the standard mean value of the bands, especially of *a* or *æ*, is slightly higher or lower than in English.

destiny. But our present system of education regards the scientific study of our native language as among the last subjects upon which to lavish its energy and enthusiasm, and scientific research in this field consequently receives but meager support.

Now it may be objected that our vowel-tone spectrum as determined by the method outlined above depends upon the investigations of a single phonetician into the nature of the tones of his own voice. But it must be borne in mind that his determinations accord substantially with those of a number of physicists of undoubted competency working independently upon intoned vowels and by quite different methods. It is the arrangement of vowel tones in the form of successive single constants which the writer's method yields that is its significant feature. When his determinations are rejected *in toto* and only those of experienced physicists working upon intoned vowels unbiased by phonetic considerations are employed, it will be found that on taking the root-mean-square of their double maximum frequency constants[17] a series of single constants, varying within comparatively narrow limits, can be obtained, which will form substantially the same increasing scale, vowel for vowel, as that given above.

The point we are stressing is that there *is a scale* of vowel tones whose degrees of quality can be scientifically measured independently of the ear, once a constant starting point is determined.

That the one we have attempted to establish bears a scientific relation to the production of language, and is no mere creation of a vagrant fancy is evidenced by the fact that it explains phenomena of language which have long been recognized.

Philologists are aware that the vowel tones of language are very unstable as compared with the consonants. With the exception of a few peculiar consonants the learner of a foreign language can quickly acquire the ability to reproduce its consonants with accuracy, because most of them are phonetically identical with those of his own. But to reproduce its vowel tones in such a way that a native will detect no strangeness in them is quite a different matter. It is also a well-known fact that it is hopeless to teach a student phonetics without first training his ear to hear the delicate variations of vowel quality which his untrained ear will never detect.

This inability to hear the finer shades of quality is, however, confined to speech sound. The untrained ear has no difficulty in

[17] A root-mean-square is a quadratic mean; since frequencies enter into energy in terms of squares, the method is quite logical, assuming that the energies of the twin maximum components are equal; if unequal, this figure will be proportionately nearer the frequency of the component which has the greater energy.

distinguishing a flute from a violin or in recognizing a person by his voice. It has already been pointed out that if the language depended upon a uniformity in all the qualities of speech tone it would be unintelligible because of the anatomical variations of individual speech organs. When we are listening to speech we identify only the major components of the tone and do not hear its minor components.

As the actual sound quality of the major components is always being modified by that of the minor components, it is obvious that the vowel qualities may be variable without impairing intelligibility of the speech gestures of which they are the nuclei.

What is the limit of this variability?

There are many known facts of phonology which point to the conclusion that the variation range of vowel quality can not cover more than two bands of our spectrum without making a given language unintelligible. We have not space here to specify these details, but we may summarize them as follows:

(1) The local variations which give some of us so much concern when disputing the correctness of English pronunciation will usually be found to be due to the shifting of one quality band to the neighboring one.

(2) The chief differences between British and American pronunciation of English are characterized by the fact that the one standardizes one band under certain conditions, and the other standardizes the one next to it.

(3) The historical development of English phonology for the last thousand years illustrates a succession of periodic shiftings of its vowel tones from one quality band to that immediately adjacent.

These facts point to the conclusion that development in language is largely due to the principle that two neighboring bands of quality constants can exist side by side in a given speech and the language still be intelligible. One of these bands becomes standard and general and the other is forgot, only to give rise to a repetition of the process.

If our theory is the true one we should expect to find confirmation of it in the historical development of the Indo-European languages as a group. Any philologist who will take down his Brugmann's "Grundriss der vergleichenden Grammatik der Indo-Germanischen Sprachen" and trace the tone developments of the various language sub-groups will find that a surprisingly large number of them conform to our principle.

We thus have in the new work in acoustic physics a means of getting at principles of language that are fundamental not only

from a mechanical and engineering point of view, but are also fundamental to a truly scientific conception of the essential nature of language, to an intelligent teaching of it as a means of culture, and to practical methods of ensuring its highest efficiency as a means of communication.

Much remains to be done along these new lines in the way of ascertaining and completing our physical data, and of determining precisely how they relate themselves to the psychology of speech production and interpretation and to the historical development of language forms and modes. But physical science has at last given us a *pou sto* in fact upon which to organize our knowledge independently of speculation and opinion.

If those who study these problems with educational and cultural aims can only be furnished with such opportunities and resources for solving them as are commanded by those who approach them from a commercial point of view, there is little doubt that the next generation will attain a complete scientific understanding of this the most vital function of man's intellectual activity.

THE STATE OF SCIENCE IN 1924[1]

THE BIOLOGICAL ACTION OF LIGHT

By Professor D. T. HARRIS

THE distribution of solar energy over the British Empire shows immensely wide variations, and inhabitants of the large cities of Britain probably receive the smallest share. It is only in recent years that the London child sufferer from tubercular joint disease has had the chance to enjoy sun baths. The pioneer work of Sir Henry Gauvain at Alton and Hayling Island has demonstrated conclusively the curative action of the sun's rays in bone and joint disease of tubercular origin. The wonderful results of Dr. Rollier in Leysin, in the Swiss Alps, show on a more extensive scale the beneficial effects of insolation at high altitudes. To Dr. C. W. Saleeby is due the credit for bringing this powerful agent to the notice of the English-speaking public. It was through his untiring efforts that the Medical Research Council appointed a committee to investigate the biological action of light, under the chairmanship of Sir William Bayliss, who was the first to write an authoritative account of this youthful and difficult subject ("Principles of General Physiology," Longmans).

The investigation of the mode of action of an agent like light, to which we and our ancestors through the ages have grown so accustomed, presents unusual difficulties; we are apt to accept it as an unanalyzable fact. No one will question the existence of the stimulating effect of the morning sun, but to determine the tissue on which it acts and its mode of action, whether chemical or electrical, is a problem demanding the cooperation of physiology, chemistry and physics.

The physicist continues to make his valuable contributions. The colors of the rainbow, which represent the visible part of the spectrum, are now known to be only a very short link in a huge electromagnetic spectrum connecting the immense waves of wireless telegraphy, on one hand, with the extremely small X-ray waves, on the other. All these waves travel at about the same speed, eight times round the earth in one second. To-day there exist but few gaps in this electromagnetic spectrum. On the red side of the visible spectrum we pass into the region of dark heat rays, includ-

[1] Prepared for the Hand-book to the Exhibit of Pure Science, arranged by the Royal Society for the British Empire Exhibition.

ing those emitted from a hot flat iron. These, though invisible, can be appreciated by the heat receptors in the skin of the cheek. Dark-heat or infra-red rays, constitute about half the energy we receive from the sun. On the more active violet side of the visible spectrum the waves are only half the length of the red waves, and as we pass beyond the faintly visible violet we come to a chemically active region called the ultraviolet, where the waves average only half the length of the violet. These ultraviolet rays are proportionally few in sunlight; they are absorbed by ordinary window glass, and so can not enter a house with closed windows. They are also reduced in intensity by absorption in the atmosphere, and hence are more abundant at high altitudes, as in the Alps.

It has been supposed that man through the long ages has become immune to the visible rays of the sun. It is only when the infra-red rays become excessive that he seeks the shade, and in this way he also escapes from the destructive action of a too powerful dose of ultraviolet light. It is the infra-red which are the potent rays in the causation of sunstroke, whilst the ultraviolet cause sunburn. The latter may be easily demonstrated by exposing an area of skin for five minutes to the ultraviolet light obtained from an artificial source rich in ultraviolet rays—*e.g.*, the mercury vapor lamp in a quartz tube; the other rays can be filtered off, the heat rays by a water cell and visible rays by a cobalt-quartz plate.

This powerful action on the human skin is of great interest. After the sunburn subsides the majority of people develop pigment. If now the same region of skin be exposed to ultraviolet light, it will be found that a burn does not appear on the pigmented skin, but only on the neighboring unpigmented skin; protection has therefore been conferred by the development of pigment. This experiment suggests the mode of evolution of the pigmented races of the tropics. How the pigment actually works, especially in view of the fact that a black body is a better absorber of heat than a white body, is a problem under investigation.

Another effect of ultraviolet light and one which has been definitely proved is its destructive action on bacteria, and this has been applied commercially to the sterilization of water by passing the water in thin sheets over quartz cylinders in which are placed large mercury vapor lamps.

Ultraviolet light appears to play a very important part in the growth and development of the young child, and may prove to be one of the chief agents in the prevention of the bony deformities known as rickets. The results of some experiments seem to point to the conclusion that ultraviolet acting alone is a more powerful agent than when acting in the presence of the visible light. Indeed,

the writer found that the stimulant action of ultraviolet light on the total chemical changes in the body could be annulled by the addition of visible light; a similar antagonizing action of the visible light was found on the tonic effect of ultraviolet on the isolated stomach kept alive with oxygenated Ringer's fluid.

As only a very short unexplored region exists between ultraviolet radiation and X-rays in the electromagnetic spectrum, it is probable that many of the problems of the biological action of these two types of radiation may be solved simultaneously. Two outstanding differences, however, exist between them. The ultraviolet rays produce their effect in a few minutes, and their direct action is entirely superficial, while X-radiation sometimes takes weeks to reveal its effects, and it penetrates deeply into the tissues, and is only stopped by dense structures like bone. The rays from radium produce effects on the tissues very similar to those of X-rays.

May we hope that the investigation of these artificial radiations in the laboratory will yield the secrets of the beneficial action of sunlight, and that man's activities will be directed to the removal from our atmosphere of the suspended matter which at present cuts off the health-promoting (ultraviolet?) rays. It is a matter for some regret that the empire on which the sun never sets has not developed great institutes for the open-air treatment with sun baths of the young victims of the darkness of our large cities.

MUSCULAR WORK

THE MECHANISM

By Professor A. V. HILL, F.R.S.

Bodily movement is an apparently simple phenomenon and its characteristics can be measured in absolute physical units. For example, the work done by a contracting muscle can be measured in ergs and as accurately as the work done by a steam engine. The mystery of how the muscle fiber performs its important and easily recognized function has long appealed to those who desired to study living response in a form approachable by methods of exact science. Moreover, there was the hope that, once a beginning had been made, the results and generalization attained by studying muscle might be found to apply to all other forms of living tissue, and so a way be found of bridging the gap between biology and physics: the continual exploration of the problem of how a muscle works was dictated by a far-seeing strategy.

The subject is full of great names, Helmholtz, Fick, Blix and many others. Of British workers Gaskell's and Mines's researches on the isolated heart have proved the fundamental basis of modern cardiology. W. M. Fletcher perceived the extreme importance of the fact that oxygen delays the onset of or abolishes fatigue in an isolated muscle: W. M. Fletcher and F. G. Hopkins, working together, recognized that lactic acid was the key to this phenomenon and that the percentage of it in a muscle is high in states such as fatigue and *rigor mortis*. From the original papers of Fletcher and Hopkins has arisen a network of investigations, illuminating many branches of physiology and throwing sidelights on several aspects of medicine and everyday life.

When a muscle contracts, lactic acid is liberated, in amount proportional to the strength of the contraction: when it relaxes lactic acid is neutralized: while the contraction is upheld, a balance is maintained between continual production and continual neutralization. During the succeeding ten minutes restoration occurs: the lactic acid is slowly removed in the "recovery mechanism" of the muscle, but only if oxygen be present; it is restored to its previous state, the necessary energy being provided by the oxidation of a fraction of the lactic acid. The system is analogous to an electrical accumulator, together with a motor and a dynamo; the accumulator can rapidly provide mechanical work when needed, but must be slowly recharged afterwards by the use of energy required to drive the dynamo. Oxygen in muscle is used only in recovery from previous exertion: even during exercise, each element of the oxygen consumption is used in recovery from a previous element of effort.

The lactic acid arises from and is restored to glycogen, a body peculiarly important in connection with modern work on carbohydrate metabolism, "insulin" and diabetes; indeed, the fact that, in muscle, glycogen breaks down more readily than does glucose into lactic acid suggests that a study of the chemical nature of glycogen and its reactions in the muscle mechanism of the frog may find some strange and interesting application to the problems of human diabetes.

The onset of fatigue is due to the accumulation of lactic acid in the muscle: the limits of violent effort are set by the maximum amount of acid which the body can tolerate. During exercise and in the earlier stages of recovery the acid passes into the blood; part of its oxidative removal may even occur in distant portions of the body. The labored respiration accompanying, and following, active exertion is due to acid in the blood stream, affecting the respiratory center in the brain. The labored respiration occurring even after moderate exercise, in some forms of cardiac or other disease, is due

to acid appearing in the blood as the result of an imperfect mechanism for its oxidative removal. The beneficial effects of previous inhalation of oxygen before a race are probably due to the solution of a store of oxygen in the tissues of the body: the beneficial effects of oxygen during recovery or in fatigue are due to the more rapid oxidative removal of the acid. The changes occurring in the blood, as the result of exercise or of oxygen want, in its combinations with oxygen and carbon dioxide, are partly due to lactic acid.

It would seem a far cry from the obscure labors of physiologists to the making of records in athletics. Yet a study of the oxygen intake and the carbon dioxide output in man, during violent exertion, together with the results of recent work on the dynamics, thermodynamics and chemistry of isolated muscle has shown otherwise. A man's capacity for muscular effort is limited by precise and clearly defined factors, depending upon his supply and utilization of oxygen, his economy in movement, his efficiency in recovery and the maximum amount of lactic acid to which his body will submit. The general type of relation existing between the distance (in a flat race) and the speed at which it can be run, can be predicted on comparatively simple physiological grounds. It has been the writer's good fortune, though himself an inconsiderable performer, to have had for many years a close personal acquaintance with athletes and athletics: and it has been recently almost a daily pleasure and excitement to find some phenomenon, known to runners, turning up again in another form in the physiological laboratory. Mountaineers, airmen, students of human movement in industry and everyday life will find the same.

We must recall, however, that it was the pure science which found the path and built the bridge, and we are really only at the beginning of our knowledge of muscle: the adventurer's instinct is still needed: it is necessary to explore as well as to exploit.

The recovery process, capable of completion only in the presence of oxygen, still goes on in part, even in its absence: the details of the process are unknown. The course and magnitude of the liberation of energy associated with all phases of contraction and recovery have been described, and it remains for the chemist to fit his details into the thermodynamic picture. Again, there are many curious and complex effects, connected with the actual shortening process itself: changes in energy liberated, changes in work done, changes in mechanical efficiency. There are the physico-chemical factors underlying the power a muscle possesses of using oxygen: there are the highly specific actions of certain drugs upon the mechanism. But behind them all remains the mystery which causes the physiologist

to smile at the simplicity of other sciences, the mystery which appeals to the artist in him, the solution of which—still so far away—offers so fruitful a field of understanding and healing men's bodies; the mystery of the little fiber, about 1/500 of an inch thick, designed and constructed in a material not unlike egg-white, growing, feeding, repairing itself and exhibiting in its function so admirable a simplicity, an efficiency and a directness of apparent purpose.

THE ENERGY OF EXPENDITURE

By Professor E. P. CATHCART, F.R.S.

ALTHOUGH man is no machine in the ordinary sense of the term, he, just like the locomotive, must be supplied with fuel for the production of work. In the case of the locomotive, however, the fuel is only required for the performance of work, whereas in the case of man the fuel—food—not only supplies the necessary energy for the performance of work, but it also serves for the repair of the wear and tear of the tissues and for growth. Before a correct assessment can be made of the amount of food required, it is necessary to determine the amount of energy expended.

This question of the best and most accurate method for the determination of the energy expended is no new one. The first experiments, which changed the whole outlook on the problem, were made almost at the same time, about 1780, by Crawford in Glasgow and Lavoisier in Paris. Crawford indeed claimed priority, but his insight into the problem was not so fundamental as that of his French rival. The method then adopted is in essentials the one we use today. It consists in the estimation, either directly or indirectly, of the amount of *heat* lost. The thermal unit or caloric is chosen because eventually all the potential energy of the food consumed or the tissues oxidized is reduced to heat, and, further, the external work done can also be measured in heat units. Thus by the use of the caloric we obtain a common factor for the statement of energy problems. The caloric used to-day by physiologists throughout the world is the large or kilo caloric which represents the amount of heat required to raise the temperature of one kilogram of water through one degree Centigrade. The amount of external work done is calculated in kilogram-meters—*i.e.*, the amount of energy expended in raising one kilogram vertically through one meter distance. Largely from the pioneer work of Joule, of Manchester, we know that approximately 427 kilogram-meters equal one large calorie.

The amount of energy, calculated as calories, contained in the food consumed is determined by burning a definite amount of the

food material, under very definite conditions, in an apparatus called a bomb calorimeter, and measuring the amount of heat liberated. A great many of the earlier determinations of the calorie values of foods were made by Frankland, of Birmingham, in 1866. The estimation of the energy lost by the living organism or man may be carried out either directly or indirectly. In the direct method, which was the one originally adopted, the amount of heat given off by an animal was measured by noting the increase in temperature of the cold water or ice which surrounded the chamber in which the animal was placed. The modern development of this method has been for the most part confined to America and is associated with the names of Atwater, Rosa, Benedict and Lusk.

The indirect method, which is much easier and less expensive, has been developed chiefly in Britain and in Germany. Although a somewhat similar method was adopted by Smith, in London, so long ago as 1859, Zuntz, of Berlin, was the first to devise a trustworthy and portable apparatus, but it had the drawback of being heavy and cumbrous. The method introduced by J. S. Haldane and C. Gordon Douglas, of Oxford, is infinitely better, being both accurate and easy to use. In this indirect method, the changes in the composition of the inspired and expired air are measured. The subject, with his nose "clipped," breathes through a special mouthpiece (or a special face-piece) equipped with two one-way valves, an inspiratory and an expiratory. The mouthpiece on the expiratory side connects by means of rubber tubing with an airtight bag which serves to collect *all* the expired air for the period of the experiment. The amount of air expired is measured by passing it through a meter, and a sample of this air is taken for analysis.

The analysis shows, as compared with the composition of the normal inspired atmospheric air, an increase in the content of carbon dioxide and a diminution in the amount of oxygen. The alteration is due to the combustion of the various foodstuffs in the tissues. The amount of oxygen used is multiplied by a factor, which is obtained from the ratio of the amount of carbon dioxide breathed out to the amount of oxygen utilized, and the result is a statement of the energy expended in calories. The assumption is made that the amount of oxygen utilized is a direct index of the amount of material burnt in the tissues. That this assumption is correct is shown by the fact that from a series of double estimations made by the direct and indirect methods the two varied in their final result by less than 1 per cent.

As the apparatus can be utilized for the determination of the energy expenditure of mobile subjects, it is possible to examine and compare the energy expended by a great variety of workers. It is

possible to assess and compare the cost of work, for example, of such very diverse occupations as postmen, riveters, tailors, clerks, etc.

If, however, it is desired to study more particularly the various phases of energy expenditure, it is customary to make the subjects perform given amounts of work on special types of apparatus known as ergometers (work-measuring machines). These machines are of different types; some are used for the investigation of work performed by the arms either of rotary or lever movement, whereas others have been devised, such as the "walking" platform and the bicycle ergometer, for the study of the cost of movement of the leg muscles. As a general rule, the work done consists in rotating a wheel against resistance which can be varied within wide limits. Under these conditions, it is possible to carry out very accurate determinations of the actual amount of work a man can perform in the course of an hour, or eight hours, or any other given unit of time.

A number of investigations have been made of the energy expenditure in various occupations by this method of indirect calorimetry, but a great deal of work must yet be done before anything like final conclusions can be drawn regarding the average energy expenditure of any class of workers. In spite of the importance of this subject, which is in reality the basis for the study of the nutrition of man, Britain possesses no institute or laboratory specifically devoted to the study of the nutrition of man, although it has at least two institutes for the study of the nutrition of farm animals.

ICE RIBBONS

By Dr. W. J. HUMPHREYS
U. S. WEATHER BUREAU

Did you ever see the Christmas ribbons Jack Frost ties about *Cunila?* If not, and if you are a lover of the beautiful in nature, then hunt for them any cold morning of early winter, when the ground is neither frozen nor covered with snow. Where? Almost anywhere along the whole Appalachian system and its borders, the home of *Cunila—Cunila origanoides,* to be exact—Jack Frost's especial favorite. A few other plants receive a little of his ribbon gifts, but mere scraps and ends left over from the lavish adornment of his particular pet.

"Cunila" is the old Latin name of a plant of some kind, no one knows what, while "origanoides" means "like origanum" (wild marjoram), whose name, also Latin, was adopted from the Greek in which it signifies delight of the mountain. No wonder then many of us, perhaps even botanists too when off their formal guard, prefer to call this aromatic herb by some simpler name, such as stonemint, or American dittany.

But call it what you will, this plant, about a foot to eighteen inches high, and having in late summer many small purple flowers, Fig. 1, is common in the eastern portion of the United States. Its somewhat angular stem has a pithy core and a woody shell threaded with long and large sap ducts, the supply tubes during the growth of the ice ribbons.

The stem dies in the autumn, but the roots live on and the sap tubes through capillary action remain full of water up to some inches above the ground. Then when a freeze sets in, from one to several, but usually two, ribbons of ice start growing out from the side of the stem, each as if (though actually not) from a wide crack or slit. The ribbons are about as thick as the blade of a table knife, half an inch to two inches broad, roughly, and of varying lengths. Those shown with the key, Fig. 2, were each about seven inches long. An occasional ribbon is nearly transparent, but the great majority are snow white. All are fibrous with a silky sheen, the fibers running lengthwise of the ribbon. Nearly all, too, are gracefully curved, as shown in the pictures, Figs. 2 and 3, and, at a little distance, look like so many large white flowers.

The earliest account of this strange ice formation that has come to my attention appeared in 1824, in the second volume of Stephen

FIG. 1. *Cunila* in bloom.

Elliot's "Sketch of the Botany of South Carolina and Georgia." In 1833 Sir John Herschel published in *The Philosophical Magazine* a brief account of the same phenomenon, though less well developed, on the stems, near the ground, of thistles and heliotropes. The first careful study of these ribbons, on a different plant however, *Pluchea* or fleabane, was made by the physicist John Le Conte, then at the University of Georgia. He found that they are owing neither to frost deposition nor to physiological action—the stem of the plant being dead—but, presumably, to the progressive freezing, at the surface of the woody portion of the stem, of water brought from the ground by the porous central pith and forced out along the medullary or pith rays. He also showed that the ribbons did not grow out from perceptible rifts or longitudinal cracks in the stem. His interesting report, presented at the third, or Charleston, S. C., meeting of the American Association for the Advancement of Science, March, 1850, is given in full in the third volume of the Association's *Proceedings*. In 1893 Lester F. Ward published a

brief and interesting description of these ribbons in volume 18 of the *Botanical Gazette;* a short, illustrated account of them, under the title "Frost Flowers," was given also in the Missouri Botanical Garden *Bulletin* for October, 1924.

However, more than sixty years passed after Le Conte's studies before this subject was again seriously examined. This last investigation, by W. W. Coblentz, published in the *Monthly Weather Review,* and also in the *Journal* of the Franklin Institute, in 1914, is the most elaborate yet given to the formation of these ice ribbons. Coblentz confirmed in the main the earlier conclusions of Le Conte, but showed that the supply of water from the ground is by way of the large sap tubes in the thin woody shell of the stem and not the central pith. He also showed that the ribbons form readily on dead stems stuck in damp soil or vessels of water, thus proving that the root system is not essential to, and presumably takes no part in, the supply of moisture. He found too that the ribbons begin as a row, along and normal to the stem, of closely spaced hair-like crystals. These are soon bound together by a connecting web of ice, and the whole grows out to a greater or less extent, a fringe at first and then a ribbon of ice. Furthermore, the ribbons form repeatedly, freeze after freeze, at the same place on the stem.

Apparently then it is established that the ice ribbon is produced by the freezing of water that rises, by capillary action, in one or

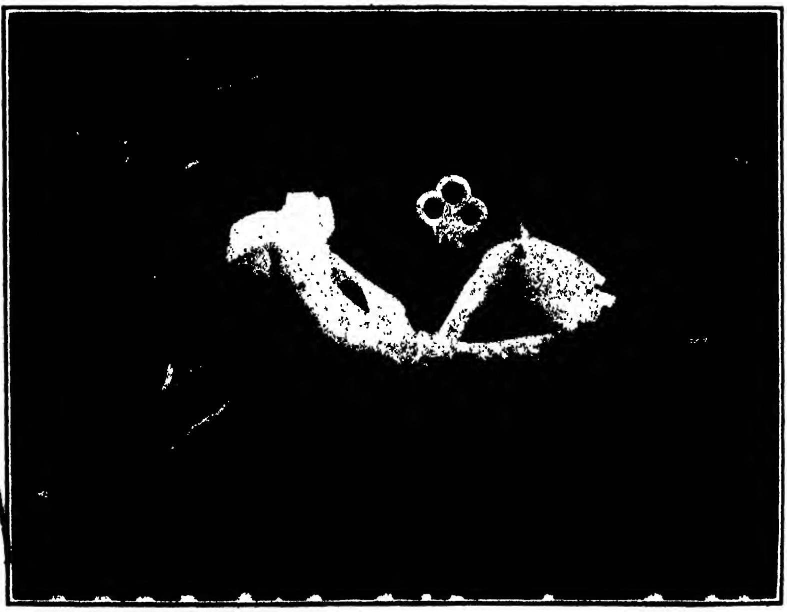


FIG. 2. A pair of ice ribbons, each about seven inches long, from a *Cunila* stem, at Huntington, W. Va., December, 1924. (Dr. L. W. Humphreys, photo.)

FIG. 3. Fibrous ice ribbons from *Cunila* stems, at Huntington, W. Va., December, 1924. Length of comparison knife handle, three inches. (Dr. L. W. Humphreys, photo.)

more sap tubes, and comes to the surface mainly, if not wholly, through a row of minute openings, and that this water comes from the soil directly and not by way of the live roots. But is the water that is fashioned into a ribbon supplied by a single tube or by many? What is the nature of the openings from the supply tube or tubes to the surface? Are they finer capillaries inherently present, or mere ruptures or partial tears incident to the drying of the dead stem, or owing indeed to some other cause? Why does not the water in the capillaries also freeze? Is this owing to the liberated heat of fusion, to impurities that the process of freezing tends to concentrate within the supply tubes, to both of these, or even, in part at least, to some entirely different factor?

But why investigate these trivial matters? Because they occur, and we do not fully understand how.

THE FIGURED STONES OF WURZBURG

A REMARKABLE HOAX IN THE HISTORY OF SCIENCE

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At no period in the history of the growth of science did there exist a greater confusion of antagonistic interpretations of natural phenomena than in the troublous times which followed the Reformation, a period embracing the latter half of the seventeenth and the earlier half of the eighteenth centuries. The rapid accumulation of new data in all fields of study clamored for correlation and interpretation; nor were correlations and interpretations wanting. Theories and counter-theories, hypotheses and counter-hypotheses were legion. Each new perplexing question propounded at once gave birth to a host of theories and interpretations more perplexing still.

Of the many vexatious problems which were presenting themselves in the rapidly growing fields of zoology and geology, perhaps the one which caused the keenest intellectual contention was the question concerning the origin and significance of fossils. The occurrence of the forms of bizarre fishes, plants, and other organic beings imbedded within the strata of the sedimentary rocks proved to be too much for the early scientific minds to explain with any degree of mutual satisfaction. The general helplessness of the majority of the paleontological scholars when confronted by this problem can be inferred from the many amusing and non-committal generalities which they advanced in explanation. Thus the presence of fossil forms in the rocks was variously accounted for by "stone making forces," "formative qualities," a growth from seeds, and the like. Even the much-abused doctrine of spontaneous generation, then almost in the heyday of its authority, was brought forward to lend its aid.

The influence of the Reformation was, at first, distinctly unfavorable, nay, even hostile, to the spread of the ideals of scientific progress. So robust was the opposition of the reformist leaders to anything like unfettered scientific research that the period immediately succeeding the Reformation was characterized by even more intolerance for the scientific viewpoint than that which marked the Reformation itself. The vestal flame of purely secular scientific philosophy was not entirely quenched, however, and later in the century it waxed stronger and more vigorous, expanding into a

FIG. 1. Some of the ''fossils'' among those first buried by the jokers.

FIG. 2. ''Fossil'' birds, some with eggs.

sturdy glow here and there, the earnest of a wider conflagration, which, at a later period, was to illumine the field of science with no uncertain light and point the way for such men as Buffon, St. Hilaire, Lyell, Darwin, and a host of others.

The old spirit of antagonism toward secular and non-Aristotelian scientific thought still retained much of its pristine power, and until as late as the middle of the eighteenth century exercised a no mean measure of judicature over matters scientific. Thus it was that when Buffon, then professor at the Sorbonne, made a modest attempt to set forth what he considered to be a body of irrefutable geological statements, the theological faculty of that venerable university, incensed at his temerity, deprived him of his honorable position in the university, forced him to recant and in the most ignominious manner to print and publish his recantation.

It was during this period of intellectual storm and stress that there was published at Wurzburg a work which stands out in prominence as a memorial at once of an almost incredible hoax, a colossal farce and a pitiful story of broken ambition and humbled pride; a work in one volume, quarto, entitled the ''Lithographiae Wirceburgensis.'' Dr. Johann Bartholomaeus Adam Beringer, its author, lived during the first half of the eighteenth century, and

at the time of the publication of the work which has made his name known held the honorable degrees of doctor of philosophy and of medicine from the University of Wurzburg, occupied a chair in natural philosophy and was private physician to the reigning Prince Bishop. He had already distinguished himself by his scholastic activities in the university, and was widely known as a capable and learned classical scholar, physician and natural philosopher. He had been the author of an able medical treatise in 1708, the "Connubium Galenico-Hippocratium," and had contributed to the literature of botany some fourteen years later in a systematic work entitled "Plantarum Exoticarum Perennium Catalogus." By his colleagues in the university he was rapidly becoming known as a paleontologist until his unfortunate venture upon the subject of the figured stones of Wurzburg, in 1726. The episode upon which the career, reputation and life of the philosopher of Wurzburg was wrecked we will now recount.

FIG. 3. Various "fossil" absurdities in modifications of marine forms.

Beringer had wholly, publicly committed himself to the belief that fossils were merely the capricious fabrications of God, hidden in the earth by Him for some inscrutable purpose; possibly, thought Beringer, merely for His own pleasure; possibly as a test for human faith. His tenure of this position became so strong and so zealous that some of the students from the university, together, possibly, with some of the members of its faculty and wags from the city, determined to put his faith in this doctrine to a trial *fort et dur.* They accordingly made numerous "fossils" of clay (Fig. 1) which they buried upon the side of a hill near Wurzburg amid some thick bushes, a spot where they knew the worthy professor was wont to ramble in his search for specimens. In accordance with their hopes, Beringer chanced upon these "fossils" in one of his geological excavating tours; was completely deceived as to their true factitious nature, and, overjoyed to discover such suppositive proofs of the validity of his views, made known the facts of his discovery at the university. The jokers, perceiving with glee the success of their trick, now went even further and buried the most fantastic

and extravagant clay figures which their whimsical imaginations could suggest (Figs. 2, 3 and 4). Not content with these alone, they fashioned inscriptions in Hebrew, Babylonian, Syrian and Arabic (Fig. 5), one of these being the name of God Himself! These they buried not far from the spot where they had concealed the first.

The elation of Beringer on discovering these latter "fossil" forms was unbounded. He was now completely convinced of the soundness of his original doctrine and at once made impressive preparations to publish a full account of his discoveries and to elaborate learnedly and at length upon their profound signification, animated by no meaner motive than to settle once and for all time the vexatious question relative to the origin of fossils.

The fervor of the once cautious man of science swept all before it, and, despite the temperate advice of more level-headed colleagues, Beringer hurried the ponderous work to its completion, and in due time the volume appeared. The book itself, a tome of commanding proportions and written in Latin, consists of an ingenious allegorical frontispiece (Fig. 6); a title page devoted chiefly to the record of Beringer's positions, degrees and honors; a dedication plate, followed by a nine-page dedication; a preface of about equal length; fourteen chapters, forming the body of the work; and twenty-one plates containing the figures. The title page informs us that the book is the: "Lithographiae Wirceburgensis, illustrated with the marvelous likenesses of two hundred figured, or rather insectiform stones," by "D. Joane Bartholomaeo Adamo Beringer, Philosophiae et Medicinae Doctore . . . etc.," and printed in Wurzburg in 1726. Some contribution to the work was made by one Georgius Ludovicus Huober, who is also mentioned on the title page, but the bulk of the work is the result of the painstaking labors of the worthy and credulous doctor of medicine and of philosophy.

The sounding and pompous dedication, nine full quarto pages long, is to D. Christopher Francis, Prince Bishop of Wurzburg, "Most Revered and Most Eminent Prince and Merciful Lord." It begins with an exposition of the frontispiece, and its significance, which is an amazing and pretentious allegorical representation of the suppositive profound signification of Beringer's discoveries (Fig. 6). In the center rises a mound composed of the "figured or rather insectiform stones," upon which recline (as significative of their debt to the truth established by the work) the patrons of the various arts, as well as teachers and children. Midway up the mound is the figure of divine child-messenger tracing upon its tablets the inscriptions which Beringer had discovered. In the foreground, to the right, stands a table, bearing the follow-

ing passage from Ovid (Metamorphoses, Bk. I, 1:436). "It [the earth] brought forth innumerable forms; some like unto those which had existed before, and some new monsters."

But the most dauntless portion of this allegorical picture is the delineation of the arms of the reigning prince and the triangle of the Holy Trinity (the latter signifying the glory of Heaven), both represented, as magnified by the work of Beringer, by being placed upon the summit of the mound!

After the preface or *Prooemium* come fourteen chapters

FIG. 5. The climax of the hoaxers' art. The "fossil" inscriptions in Hebrew!

FIG. 4. "Fossil" comets, stars, crescent moon, and a minor sun with a face!

containing a full account of the discovery of the stones, the methods which the author had used to safeguard himself, as he thought, against making errors in the interpretation of his data, the description of the hill where the digging had been carried on, the progress of the work at the university, and so forth. He carefully refutes in advance the view that the figured stones might possibly be vestiges of the early "pagan" occupation of the land, *i.e.*, the occupation by the Gauls. We can picture to ourselves the fervor of the old scholar as he labored over his great work, the *magnum opus* of a life of scientific devotion, his thoughts dwelling fondly, and not a little proudly, perhaps, upon the expected acclamation with which the book would be greeted by his contemporaries in science and philosophy. Not only would his proofs of God's direct agency in the formation of fossils be the

coup de grace to purely secular science, but it would undoubtedly forever lay the ghost of that troublous matter of the origin and meaning of fossil forms. No doubt the idea of the allegorical frontispiece came only after he had labored long upon the manuscript of the "Lithographiae" and had pondered over the enormous authority which it would one day wield in the world of scientific thought. In chapter after chapter the author anticipates and

FIG. 6. The exuberant frontispiece of Beringer's great work. Note the arms of the reigning prince and the triangle of the Holy Trinity surmounting the mound of "fossils"!

refutes objections to his views concerning the *lapides figurati Wirceburgensis,* always reverting to his tenet of their fabrication and concealment by divine decree. He describes gravely the Hebrew, Arabic, Babylonian and Syrian inscriptions which he had unearthed, commenting upon the nicety with which they had been fashioned, and upon their excellent state of preservation. Some of these inscriptions occur on shells and images of animal forms.

And now comes the strangest part of this humiliating story. Some of Beringer's friends, partners to the secret, alarmed at the

length to which he was pursuing this prodigious fraud, endeavored to dissuade him from the publication of his book. And even though others, who knew more intimately the secret of the trick which was being played upon him, acquainted him fully with its shameful history, yet he obstinately refused to give their stories credence. In one contemptuous chapter he dismisses all their evidence, denouncing it as a ruse of his rivals to deprive him of the honor of making known his discoveries, and of publishing so important a contribution to science. He argues that, since the workers employed by him to unearth the fossils knew no tongue save their own, they manifestly could not have made inscriptions in Hebrew, Arabic, Babylonian and Syrian. Needless to say, he had first convinced himself that no one save he and the workers (as he says, "some boys of tender age") had ever set foot upon the mountain whence had come the marvelous insectiform stones.

His work being at length completed, and in spite of the now more robust efforts of his colleagues to prevent publication, he published it and appealed to the learned world. But the shout of laughter with which the book was received was not to be misinterpreted. In chagrin, anger and despair, the broken-spirited man exhausted virtually his entire fortune in the fruitless endeavor both to suppress the publication of the book and to buy up all the copies which had been issued. For a short time he lived, the object of the mingled ridicule and pity of his contemporaries, and not long after died, as tradition tells us, of a broken heart.

But the wrecking of Beringer's reputation did not cease with his death, for a graceless bookseller, Hobhard of Hamburg, seeing his opportunity to make capital of Beringer's shame, bought up all the available copies from the heir of the original publisher and not only reissued them, but, compiling a second edition, brought out the work under a new title and turned this also into circulation!

Poor Beringer! His woes have been great, and his demand upon posterity is one for large pity. Very few of the prominent personages in the history of science stand so in need of our heartfelt sympathy as Johann Bartholomaeus Adam Beringer, doctor of philosophy and of medicine in the University of Wurzburg, and private physician to the Prince Bishop.

(For accounts of Beringer's work see, first of all, the "Lithographiae" itself. None of the accounts are complete, and give but short résumés; these are: Allgemeine Deutsche Biographie, Vol. 2; Ersch u. Grüber, Encyclopädie d. Wiss u. Künste, Leip. 1818–90; Reusch. Bibel u. Natur, Freiburg, 1866; Reuss, Litterarisches Curiosum, in the Serapeum, 1852, Vol. 13; Zöckler, Geschichte d. Beziehungen zw. Theologie u. Naturwissenschaft, Gutersloh, 1879, Vol. 2, p. 171.)

YOUTHFUL ACHIEVEMENTS OF GREAT SCIENTISTS

By GEORGE P. MEADE
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SOME years ago Dr. Osler gained much publicity by something he did not say. He was credited popularly with saying that all men over 40 were useless and advocating chloroform for all men at 60. According to the International Encyclopedia what he did say was, "Take the sum of human achievement in action, in science, in art, in literature; subtract the work of the men above 40—we should practically be where we are to-day."

The forty-year mark seems to have been set by many observers as the limit beyond which fame is not likely to be gained. Oliver Wendell Holmes has been quoted as saying, "If you haven't cut your name on the door by the time you've reached forty you might just as well put up your jack-knife."

In the scientific world the critical age seems to be much lower. The scientist who has passed thirty and has made no noteworthy discovery is not likely to; and to be a world figure, one of the men whose discoveries make up scientific history, it seems necessary that something of real worth should be done before reaching twenty-five.

The points which this study will try to bring out are these: (1) that scientific genius manifests itself at an early age (usually before twenty-five, sometimes before twenty); (2) that this early work is not mere student activity, but original work of great importance and (3) that frequently it is the *most* important work of the man's career. This last point is the one of greatest interest—that so many men's names have come down to us because of the work which they did in their twenties.

In connection with this idea it can be shown that in many cases where the greatest work was not accomplished until late in life, the basic thought, or underlying *idea* of the work originated much earlier—that is, the man spent his life working out ideas which occurred to him before he reached thirty.

No claim is made that great work has not been done by men over forty. Such a claim could be too easily refuted by numerous illustrations to the contrary, but it can be said that in general the important contributions made after forty were extensions of ideas originated before that age was reached.

Galileo was eighteen when he discovered that the vibrations of the pendulum are isochronous, and within four years he had published his work on the hydrostatic balance and the center of gravity of solids. A year later, at the age of twenty-three, he evolved the laws of falling bodies. It has been said that by this discovery Galileo "probably contributed more to the physical sciences than all the philosophers who had preceded him." No mean achievement at twenty-three!

Sir Isaac Newton, "the greatest genius that ever existed," born in 1642, entered Cambridge at the age of nineteen. He promptly mastered all the mathematical works then existing, and the year before he graduated he formulated the general binomial theorem. He took his B.A. degree early in 1665 and before the end of that year had discovered the method of tangents and differential calculus, followed six months later by integral calculus. Thus, in his twenty-third and twenty-fourth years his contributions to mathematics were greater than the complete life work of any man before or since. In 1666 he began to study the action of gravity on the moon and propounded a part of his famous theory of universal gravitation. He failed to prove the theory at that time, because of an erroneous figure for the radius of the earth, then extant, but had his data been correct he might have made at the age of twenty-four, instead of some years later, the greatest contribution to science the world has ever known. He dropped the idea for several years, turning to optics and the study of light, and invented the reflecting telescope before he was twenty-six.

Newton himself said of the years 1665 and 1666, "for in those days I was in the prime of my age of invention, and minded mathematics and philosophy more than at any time since."

Huyghens, the distinguished Dutch physicist, wrote on the quadrature of the circle and ellipse at twenty-two, invented the pendulum clock in 1665 when he was twenty-six, and that same year was the first to explain the excrescences of Saturn as rings.

Mathematicians seem to be especially notable for their youthful achievements, possibly because mathematics requires no laboratory, no experimentation or elaborate collection of data on which to base its findings.

Leibnitz, codiscoverer of the calculus with Newton, first took up law and wrote many legal disquisitions of high merit between sixteen and twenty. He was eminent in history, divinity, philosophy, politics, mathematics, mining engineering and literature. His discovery of differential calculus came when he was twenty-nine years of age.

Pascal, born in 1621, was a "boy prodigy." He learned geometry surreptitiously at twelve, published at sixteen a work on the "Geometry of Conics," which contains the theorem that bears his name, and made the first computing machine at eighteen.

The famous Bernouilli family produced eight eminent mathematicians in the seventeenth and eighteenth centuries, many of whom were youthful prodigies. Nicholas Bernouilli spoke four languages at the age of eight, took his doctorate at Basel at sixteen and was full professor of mathematics at twenty-one.

D'Alembert (1717–83), French mathematician, philosopher and encyclopedist, published a scholarly treatise on integral calculus at twenty-two. His "Treatise on Dynamics" in 1743 (twenty-six years old) "marks an epoch in mechanical philosophy."[1]

Laplace (1749–1827), the greatest of French astronomers, published "Researches on Integral Calculus" before he was twenty, followed within the next four years by a series of brilliant memoirs on the theory of probability, which were the object of special commendation by the Academy of Sciences.

Leonhard Euler (1707–1783), a Swiss, one of the most prolific and versatile mathematicians of all time, received his master's degree at sixteen and wrote an essay which received a prize from the French Academy of Sciences at twenty. He was professor of physics at St. Petersburg at twenty-three and professor of higher mathematics at twenty-six.

J. L. LaGrange (1736–1813) was "pronounced the greatest mathematician living at the age of twenty-five."[2]

Karl Frederick Gauss (1777–1865), one of the most brilliant mathematicians of modern times, is said to have been able to do cube root in his head at the age of eight. He was in possession of the idea of least squares at eighteen (although he did not publish his work on this subject until 1808) and made several important mathematical discoveries before he was twenty. He published a work of far-reaching importance, "Disquisitiones Arithmeticae," when he was twenty-four.

In the field of chemistry we have many instances of epoch-making discoveries by very young geniuses. Joseph Black demonstrated the nature of carbon dioxide before he was twenty-six, reporting it in his doctor's thesis in 1754. "He is best remembered by chemists for this work," says Moore in his "History of Chemistry." Lavoisier (1743–1794), "the father of modern chemistry," was awarded a gold medal in 1766 (twenty-two years old) from the Academy of Sciences in recognition of a paper dealing with

[1] International Encyclopedia.

[2] Sedgwick and Tyler's "Short History of Science."

the problem of lighting a large town. In 1770, when he was twenty-six years old, he published the first of his many experiments on combustion which ultimately led to the overthrow of the phlogiston theory and the establishing of our modern conception of combustion.

In 1802, at the age of twenty-four, Gay-Lussac enunciated the law generally known by his name. Sir Humphry Davy was twenty years old when he discovered the physiologic properties of nitrous oxide, twenty-two when he was made professor of the Royal Institution and twenty-six when he isolated sodium and potassium electrolytically.

Michael Faraday might have been expected to be an exception to the rule that genius will manifest itself at an early age, since he was a bookbinder's apprentice with little schooling, when he entered Davy's employ at twenty-three. Yet "within two or three years he was making discoveries in both chemistry and physics which rivalled in quality those of his master."[3]

Liebig took his doctor's degree at nineteen and was full professor at Giessen at twenty-one, founding the first laboratory for chemical instruction along modern lines, and was dominating the whole field of organic chemistry within a few years. Wöhler, his close personal friend, was already widely known when he discovered aluminum at twenty-seven. He was only twenty-eight when he synthesized urea, the first instance of organic synthesis, sometimes referred to as the beginning of modern organic chemistry.

Mitscherlich, born in 1794, first studied history and philology and wrote a creditable paper on Persian history at twenty. The following year he began a course in medicine and immediately turned his attention to the study of crystalline form and its relation to chemical composition, the branch of chemistry in which his principal work was done. At twenty-five he published his brilliant paper on "Isomorphism," in which he stated the principle that "the same number of atoms combined in the same way produce the same crystalline form." Thomas Graham's studies on diffusion of gases, which led to the discovery of his famous law of diffusion, were begun at twenty-four. The first of Williamson's classic researches on the ethers was published in 1850 when he was twenty-six. Gerhardt at about sixteen "showed the natural bent of his genius by attempting a classification of the silicates which won commendation from Berzelius."

At twenty-three, Berthelot, whose fame rests largely on his work in thermo-chemistry, made the first of the direct organic syntheses by passing alcohol, acetic acid and other simple sub-

[3] Moore's "History of Chemistry."

stances through heated tubes, thus preparing benzene, phenol and naphthalene. This work and more of the same type which he published soon after gave the first great impetus to organic synthesis and set chemists to thinking about the preparation of all kinds of complex natural compounds by laboratory processes.

Bunsen, born in 1811, took his doctor's degree at Göttingen in 1830 (nineteen years old). His work on cacodyl at twenty-five was of such high class that "it alone would have assured him recognition." Dumas did some work on the chemistry of the blood at twenty-one which surpassed any work previously done on that subject, attracting the attention of Humboldt.

A striking instance of youthful achievement in chemistry is that of William Perkin, who, while a student of Hoffman's in 1856, discovered the first artificial dyestuff ever produced—"the celebrated experiment which was to give the seventeen-year-old lad immortality." He immediately left Hoffman's laboratory and entered into the commercial manufacture of the product he had discovered, overcoming practical difficulties that made the actual discovery seem a small affair, and establishing himself before he reached twenty as the founder of the coal tar color industry.

Pasteur's work at twenty-five on the relationship between the crystalline form and the optical activity of the salts of tartaric and racemic acids was of far-reaching significance. "Thus at one step Pasteur gained a place of honor among the chemists of his day."[4] Soon afterward, in studying methods for the separation of racemic mixtures, he found that the mold, penicillium glaucum, would destroy one form of crystal and not the other, and this discovery led him into other work with microorganisms which ultimately made him the greatest scientific figure of the century.

Coming down to more recent times we find that two of the basic theories of modern chemistry were formulated by young men not yet graduated from their universities. Van't Hoff in 1872 was just twenty-two when he published a pamphlet setting forth all the fundamentals of what we now know as stereochemistry, or the arrangement of atoms in space. LeBel, who formulated the same ideas independently of Van't Hoff, was himself a student at the time.

The second case was that of Arrhenius, who stated the general principles of his theory of electrolytic dissociation in his doctor's thesis when he was just completing his studies at Stockholm. It was three years later that he promulgated the theory in the form that we now know it, but the basis of the idea was set forth by him when he was only twenty-four years old.

[4] Encyclopedia Britannica.

In his "Eminent Chemists of our Time," Benjamin Harrow gives eleven biographies, choosing those chemists who have done most to influence the science during the last fifty years. Three of these, Perkin, Van't Hoff and Arrhenius, have already been shown to be shining examples of early manifestations of genius. Three others, Theodore Richards, Victor Meyer and Emil Fischer, are further examples.

Richards, whose work on the atomic weights won him the Nobel Prize in 1914, a distinction that has come to no other American chemist, started on this work before he took his doctorate at twenty. In two researches marked by novelty of procedure and extraordinary care in manipulation, he determined that the accepted atomic weights of oxygen and of copper were too high. "The boy Richards had become a force to be reckoned with."

Victor Meyer received his doctor's degree at Heidelberg at nineteen, "Summa cum laude," which is given only rarely. Within the next three years he published several important papers, and at twenty-three he announced his discovery of the nitro compounds of the aliphatic series. He was a full-fledged professor at Zurich at twenty-four. His classical work on vapor density determinations was begun before he was twenty-eight.

Emil Fischer, possibly "the foremost organic chemist of all times," according to Harrow, discovered phenyl hydrazine at twenty-three "and forged to the very front rank of organic chemists." "He belonged to the four or five leading chemists of Germany" before he reached thirty.

Two of the others cited by Harrow, Mendelejeff and Remsen, had published text-books of recognized value before they reached twenty-eight. Mendelejeff's Periodic Law was not published until 1869, but Harrow suggests that the idea of the possible relationship among the elements may have come to him through hearing Cannizarro at the Karlsruhe Congress of Chemists in 1860 when Mendelejeff was twenty-six.

Of the remaining three in Harrow's list, Madame Curie discovered radium at thirty, Henri Moissan isolated fluorine at thirty-two, followed a few years later by his other great contribution, the electric furnace, while Ramsay was the only one of the eleven whose fame was gained after forty. His work on the rare gases of the atmosphere, beginning with the discovery of argon, started in 1894 when he was forty-two. It should be added, however, that Ramsay did much valuable physico-chemical work, particularly on the thermal properties of solids and liquids, before he was thirty and that "his reputation was such that he was elected a Fellow of the Royal Society" when he was thirty-six.

Among the physicists, Carnot's epoch-making researches in the theory of heat were begun when he was twenty-three and his famous "Cycle" was published in 1824 at the age of twenty-eight; "Thus the new science of thermodynamics was born." Joule published his work on the relation of heat to mechanical force (Joule's equivalent) in 1842 when he was twenty-four; Mayer's work on the same subject was published at twenty-six; Clausius formulated the second law of thermodynamics at twenty-eight (1850).

In 1847 Helmholtz, then twenty-six years old, stated the law of the conservation of energy in "one of the most remarkable papers of the century."[5] Helmholtz had already distinguished himself at twenty-one by a thesis announcing the discovery of nerve cells in ganglia.

Lord Kelvin, then William Thomson, wrote a paper containing the germ of his theory of the age of the earth when he was eighteen, a subject which he elaborated on greatly in his later years. A paper on the motion of heat in solid bodies was favorably received by scientists while he was still an undergraduate. He graduated from Cambridge at twenty-one and made his important contributions to thermodynamics in 1848–49 in his twenty-third and twenty-fourth years.

Of the physicists who are best known for their work on light Thomas Young (1773–1829) explained in 1793 the mode in which the eye accommodates itself to distances through changes in the curve of the lens. In 1794 he was elected Fellow of the Royal Society (twenty-one years old) and in 1800 at twenty-seven he published two works containing most of his important researches. One was on the "Mechanics of the Eye," and in it he explained astigmatism, how the eye perceives color, color blindness and many other phenomena; hence he has been called the founder of the science of physiological optics. The other work on "Theory of Light and Colors" contained his researches on the interference of light, which ultimately led to the proof of the wave theory. Incidentally at fifteen Young was acquainted with Latin, Greek, Hebrew, French, Italian, Persian and Arabic, and in his later years he was a distinguished archeologist.

Fresnel put forth his proof of the undulatory theory of light in 1815 when he was twenty-seven. "No contribution to the theory of light is more important." Arago, who was associated with Fresnel in many of his later researches, was made a member of the French Academy at twenty-three, the rules as to age being suspended in his favor because of his work with Biot in the measurement of an arc of the meridian. In 1811, at twenty-five, Arago

[5] Sedgwick & Tyler's "Short History of Science."

read before the academy a paper of fundamental importance on chromatic polarization. At twenty-six he began his extraordinary course of lectures on astronomy which fascinated all Paris—both savants and public. He supported Fresnel's contributions regarding the theory of light and worked with him on several investigations.

Foucault, Fizeau and our own Michelson all contributed their work on the velocity of light before they reached thirty.

James Clerk-Maxwell (born 1830), one of the greatest of modern physicists, was very precocious. His first scientific paper "On the description of oval curves" was read for him before the Royal Society of Edinburgh before he was fifteen. He wrote two valuable papers, "On the theory of rolling curves" and "On the equilibrium of elastic solids," before he was eighteen. His great researches on electricity and magnetism began in 1856 when he was twenty-five. In 1857 he received the Adams prize from Cambridge for his paper on "The stability of motion of Saturn's rings."

Turning now to the naturalists, we find that Linneaus (1707–1778), "who established the science of botany," showed much energy in planting, collecting and observing all manner of wild growths before he was ten years old. Botany absorbed all his interest to the exclusion of his regular studies, so that at seventeen his father despaired of his studying for the university and wished to apprentice him to a tradesman. Fortunately, a physician in the town recognized Linneaus's ability "and had the rare experience of bringing a young man to his life work; and this circumstance illustrates most strikingly the wisdom of directing the young mind into its natural channels."[6] At twenty-two Linneaus wrote on the sexes of plants and at twenty-eight published his famous "Systema Naturae" which went through twelve editions, followed before he was thirty by several more of his greatest works.

Geoffrey St. Hillaire (1772–1844) was only twenty-one years old when he became professor of vertebrate zoology in the Museum of Paris. Cuvier (1769–1832), "founder of the science of comparative anatomy," was recognized as a genius at twenty-five and was made an original member of the institute on its organization in 1795. At twenty-nine he published the first classification of animals on which so much of his fame rests.

Alexander Von Humboldt (1769–1859) made his first important publication on geology at twenty. He was made superintendent of mines of Bayreuth at twenty-two because of his essays on the cryptogamous plants of the mines. He made numerous notable contributions to science in chemistry, physics and geology before he reached thirty.

[6] International Encyclopedia.

Thomas Huxley (1825–1895) graduated as medalist of the University of London in 1846. His research on "The anatomy of the Medusae," published before he was twenty-five, "placed the author in the first rank of biologists" and "stands as the basis of modern philosophical zoology." He was elected fellow of the Royal Society at twenty-six and given its medal the following year.

Sir Charles Lyell (1797–1875), eminent contributor to geological science, studied law and was admitted to the bar at twenty-six, but while pursuing his professional duties he was a frequent contributor to the Geological and Linnean Societies of London. The value of this work was recognized by Cuvier, Helmholtz and others, and he was elected a fellow of the Royal Society at twenty-nine. His great work, "Principles of Geology," published when he was thirty-three, marked an epoch in geological science and ranks with Darwin's "Origin of Species" in affecting the thought of the nineteenth century.

Louis Agassiz (1807–1873) at nineteen prepared a description of Spix's collection of Brazilian fishes which attracted the attention of Cuvier. Agassiz's work on the theory of glacier formation was propounded before he reached thirty.

Johannes Müller (1801–1858), the most masterful, accurate and influential physiologist of his time, wrote a prize essay on the "Respiration of the Foetus" at twenty, an important research in specific nerve energies at twenty-five and his colossal work on general pathology at twenty-eight.

Theodore Schwann (1810–1882), physiologist and histologist, discovered pepsin at twenty-five and contributed his most important achievement, the foundation of the modern cellular theory, at twenty-nine. The Swiss botanist Karl Naegeli (1817–1891), one of the greatest names in the history of botany, published the most striking of his many and varied discoveries in his *Zeitschrift für Wissenschaftliche Botanik* in 1844–1846 (twenty-seven to twenty-nine years old). These discoveries related to cells and cell formation and to plant protoplasm.

The point which has been referred to before, that many men who gave final formulation to their greatest work late in life had the idea much earlier, is well illustrated in the case of Darwin. He published the "Origin of Species" when he was fifty, but the idea of the theory of natural selection came to him twenty-four years earlier while he was in the Galapagos Islands during the famous trip of the *Beagle*.

One of our newest branches of science, radio-activity, may be said to have been founded by Madame Curie when she discovered radium and polonium at thirty. The work of Rutherford on the

radio-activity of thorium in 1900 when he was twenty-nine was of far-reaching importance. Soddy, who was associated with Rutherford on some of his further researches on thorium, was twenty-five when this work was published.

Of Moseley's studies of the X-rays derived from different sources which led to his discovery of the atomic numbers in 1913, Professor Millikan says, "In a research which is destined to rank as one of the dozen most brilliant in conception, skilful in execution and illuminating in results in the history of science, a young man but twenty-six years old threw open the windows through which we can now glimpse the subatomic world." Moseley was killed in the war at twenty-seven.

While inventors can not strictly be classed as scientists, it may not be out of place to close with a list of those who have earned the right to fame in their twenties.

James Watt started his work on the steam engine at twenty-four, completing it at twenty-eight; Eli Whitney patented the cotton gin when he was twenty-eight; McCormick the reaper at twenty-two; Howe the sewing machine at twenty-six. Edison was twenty-six when he invented his system of multiple telegraphy and twenty-nine when he brought out the phonograph. Bell patented the telephone at twenty-nine; Brush his dynamo-electric machine at twenty-six and the arc light at twenty-seven; Westinghouse the air brake at twenty-two. Hall's process which made the manufacture of aluminum a commercial success was patented at twenty-three.

Wells, Morton and Long, each of whom claims priority in the discovery of the use of anesthetics for surgery, were all under thirty when their work in this field was completed.

In collecting the facts for this article it has been necessary in the majority of cases to take the date of publication as the time when the work was done. This may be misleading, particularly where a man published a number of researches in a single treatise, since it is obvious that some of these researches must have been completed considerably earlier than the publication date. Even the most detailed biographies frequently fail to fix the time when an important piece of work was accomplished.

Throughout this study the writer has been impressed by the number of young scientists whose work has been influenced by some teacher or other person who encouraged and directed the youthful enthusiasm. "His work attracted the attention of so-and-so." "At the university he came under the influence of the great so-and-so." "His father early recognized and fostered his ability." "To Professor —— must be given much of the credit for his interest in the science." These and similar phrases occur

with noticeable regularity in the encyclopedias and biographical works from which the data for this article have been gained. It must follow that the opposite is true, that many early enthusiasms have been killed and many an incipient discovery blanketed through indifference or discouragement on the part of some educator.

We hear on all sides criticism of the prominence of athletics in our university life, but it may be that the educational side might take a leaf from the methods of the directors of athletics. Under the intensive athletic training in the American colleges no athletic talent escapes. Not only is the evident athlete encouraged; incipient prowess is fostered and latent ability is brought to the surface and developed. No opportunity for arousing enthusiasm by example is lost sight of. The visit of Nurmi, the Finnish distance runner, is made the occasion for increased interest in this branch of athletics and as a consequence new champions will be developed and new records set.

Was the visit of Einstein (who by the way propounded his theory of relativity at twenty-six) taken advantage of by our educators to increase the interest and arouse the enthusiasm of our students of pure science?

QUACKS AND QUACKERIES

By Dr. J. HEYWARD GIBBES
COLUMBIA, S. C.

The term "quack" seems to have been introduced into our language by the duck. But the sound itself could not have given it recognition. It was the loudness and the meaninglessness of the duck's utterances that we have accepted as the crying of worthless wares, the pretending to virtues that do not exist and the professing of deeds that can not be accomplished. Originally the term, as applied to medical fakirs, was "quacksalver," indicating one who was a charlatan in matters pertaining to salves or remedies. It must have been thought necessary, in the beginning, to differentiate the medical quack from all the other varieties of quacks—religious quacks, literary quacks and philosophical quacks. But the irregular practice of the healing art seems to have proved so profitable that the numbers engaged in it became so great as to effectively obscure the quacks of other professions, with the result that the term has now come to mean, almost specifically, one who professes to cure the sick by means that differ from the generally recognized medical procedures, or one who lays claim to esoteric knowledge which is to be magnanimously used but not imparted.

The relatively high scientific plane that has been reached by modern medicine is so far above the humble origin of this art as to require a magnifying glass, or at least close discernment, to bring out the resemblance between parent and offspring. The truly marvelous advances of science, especially in the fields of chemistry, physics and biology, nearly all of which have found their application to practical medicine, have lifted medicine far away from its early companions, mysticism and magic. But it is useful for us to look back upon the early priest who cast out the demons of disease with incantations, charms and spells, the compounders of mummy pills and the hardy prescribers of theriac. Nor should we lose sight of the fantastic theories of disease that were entertained by our lineal, and, in many cases, respected forebears. Pythagoras's doctrine of mystic numbers, Galen's weird ideas of anatomy and physiology, and the polypharmacy of the recent past should all serve to curb our arrogance and keep us humble. Virtue does not exist without vice; the one is dependent for its existence upon the other, and it is well to keep the com-

plemental relationship in mind in attempting to form our estimate of good and bad. In THE SCIENTIFIC MONTHLY for March, 1923, the following appeared under the title of "The ancestral scandals of science":

Tracing back the history of a science is like searching out a genealogy; one is sure to unearth something scandalous if he goes back far enough. John G. Saxe warned the would-be ancestor worshipper of this danger in the following lines:

> Depend upon it, my snobbish friend,
> Your family thread you can't ascend,
> Without good reason to apprehend
> You may find it waxed at the farther end
> By some plebeian vocation!
> Or, worse than that, your boasted line
> May end in a loop of a stronger twine,
> That plagued some worthy relation.

The chemist handles with reverent awe the latest unearthed and earliest written text of his science, a scrap of Egyptian papyrus, but when he gets it translated he finds it is a counterfeiter's receipt, a method of making base metals look like gold. Or else it is a receipt for a cosmetic, which is also a form of counterfeiting.

The astronomer finds in a Babylonian brick the first record of the stars but discovers to his disgust that the cuneiform inscription is an astrological treatise, a fortune-teller's handbook.

Hero of Alexandria described the turbine steam-engine, the coin-in-a-slot machine and other valuable inventions. But what were they invented for? So the priests of the temple of Isis could perform fake miracles.

Pythagoras discovered the law of hypotenuse—and was so happy over it that he killed a hundred oxen. It is hard for us to see why. But mathematics was to him a form of magic, otherwise he would not have been interested in it.

Paracelsus did much to advance medicine. We can not yet dispense with the three drugs he introduced, mercury, opium and antimony. But Paracelsus's real name was Bombast—and he lived up to it.

It is humiliating to confess, but the progress of science in its early days owed much to the false pretensions of its practitioners. Kings would not have kept a corps of men studying the stars unless they had proffered practical returns in the way of auguries. Chemists were subsidized for centuries because they promised the philosopher's stone and the elixir of life—promises not yet fulfilled.

Columbus would not have ventured to cross the Atlantic if he had not been wrong in his figuring about the size of the earth, and his royal backers would not have put up the money for the voyage if he had not told them wrongly that he could reach India that way.

Ponce de Leon was led to Florida by his search for a mythical Fountain of Youth. Coronado explored the Kansas plains to find the fabulous Seven Cities of Cibola. The vain search for the impracticable Northwest Passage to Asia was the stimulus to exploration for a century.

Fortunately for the world, fictitious aims may lead to real results. The scientist has learned to achieve greater miracles than he ever pretended to perform. Truth has grown up under the shadow of error as infant oaks get their start under the shelter of worthless weeds. In chasing a will-o-the-wisp, one may catch sight of a fixed star. Falsity has often served as a guide to Truth.

With these thoughts before us we might approach the subject of quackery in general with a very tolerant attitude, and at least an inquiring spirit. There is too much success in such practice to make it unworthy of thoughtful consideration, and we are all too prone to sacrifice this kind of consideration to prejudice and resentment. There can be no doubt but that there have been quacks who were sincere in their professions, and, in such cases, they have been guilty of nothing more than an error (not an uncommon fault); fanatical zeal doubtless has something to commend it; malicious misrepresentation, nothing. Intolerance and resentment on the part of the regular medical profession toward quacks have never done them harm. The layman looks upon such conduct by the physician as an expression of his chagrin at the encroachment into his field of a newcomer, and the quack is likely to profit by, rather than suffer from, attacks that are made upon him from this quarter.

There is much of interest in the history of quackery. Some of these men have been endowed with dynamic personalities, the type that are the "observed of all observers," and who put it across with little more than this. Some have been highly educated, if attendance upon universities can be accepted as a standard; while others have seemed to succeed through the sheer force of their ignorance. In addition to the interest which this subject holds for us, there is amusement and pathos in it.

There seem to be two main avenues through which quackery finds access to human credulity. It is either through the claim of a divinely inspired personality or the development of a doctrine concerning the cause and cure of disease which differs radically from the commonly accepted ideas, the doctrine being surrounded with words and phrases which have a euphonious sound and little meaning. The personally inspired healers find their anchorage in the religious beliefs and traditions of all ages; for, in primitive society, as well as in our supposedly advanced civilization, the incarnate gods, or even the secular representatives of the gods, have had healing powers and practices attributed to them. The average person seems to think that this is too good a chance to pass up, and when some one announces that divine guidance has been received, or instruction given for the cure of the sick, the sufferers are in turn inspired with hope, and they come in flocks for assistance. These claims are not always the product of cupidity; in fact, the success which attends them often depends upon the fanatical sincerity of the testifier. The substantial changes in the national life of France which were brought about by the hallucinations and delusions of Joan of Arc serve to illustrate the peculiar

appeal and impelling force of these phenomena. But quacks who enter by this approach most often have a rapid rise, a brief period of glory and an equally rapid descent. Their appeal is entirely to human emotion, a flimsy ground which soon gives way under them.

The more or less organized systems of quackery which have been evolved from time to time have usually been developed from a fanciful variation of commonly accepted knowledge. Germs of psychological truths have been magnified into distorted doctrines of the cause and cure of disease, electrical phenomena have stimulated the imagination to weird ideas in connection with its application to the seeking after health, a smattering of anatomy has led to peculiar generalizations, and misinformation concerning the use of drugs has resulted in the appearance of systems that are drugless, drugful and homeopathic. Here we have the development of so-called cults, sects, etc.; and they endure in spite of demonstrated error. Why they should is somewhat difficult to understand. The only explanation immediately apparent is the germ of truth and the cloak of words, words, words. These are the practices which so often arouse our wonder at the gullibility of mankind, and not infrequently make us resentful at the impositions which are practiced. But we should keep in mind that, even here, sincerity seems to be the rule rather than the exception in the founders of these cults. In most instances, brooding or hysterical individuals, reacting against the deficiencies of regular medicine, or having *experiences* which appeal to them as revelations, enthusiastically launch their ideas, and they find a sympathetic reception in the minds of other brooding and hysterical people who have suffered from the failures of doctors or medicine. On the other hand, we shall find instances of undoubted malicious exploitation.

There is an abundance of literature dealing with the lives and practices of the individual quacks of the past. Space will not permit of a detailed review of this fascinating subject. We shall just touch the high spots sufficiently to indicate the forms of weirdness in ideas that have successfully imposed upon mankind's gullibility.

It is questionable as to whether we should class the practices of the primitive priest, the incantations, the amulets and charms, the mystic dances and other rites which were employed for expelling the demons of disease from the human body as quackery. It is almost certain that these ancient magicians, the forerunners of our doctors and ministers, believed as firmly in the efficacy and propriety of their acts as their successors do in theirs to-day. The hepatologist and other prognosticators of ancient times are doubtless entitled to equally considerate treatment. We may not agree

entirely, but there is much to be said in favor of the idea that "there is nothing either good or bad but thinking makes it so," and it is probable that these early seers were using the best information at their command.

The astrologers, crystal gazers, alchemists and others of like ilk bring a doubt into our minds as to whether they are deserving of leniency. Their parasitic attachment to royalty, their high position at court, their material well-being and their oracular utterances make us wonder if they were not playing on the kings like fiddles and marking time with their practices on the lesser peoples.

The power of personal healing has always been conceded to be a godly attribute, and the idea has held throughout the ages that the gods might delegate this power to their chosen representatives. It is through this means that the kings of France and England derived their rights to touch their subjects for the cure of disease. Here we have a long list of royal quacks. Philip I of France (1061–1108) is our first authentic record of the royal charlatan, with Edward the Confessor (1066)—inaugurating the custom in England, and Queen Anne and the Stuarts having the hardihood to carry the custom into early modern times. Thus, our quack might be said to keep good company.

Valentine Greatrakes asked no odds of royalty and achieved equal success with the best of kings in curing disease by the simple laying on of hands. He claimed that he received his commission as a healer directly from high heaven through dreams that came to him on three successive nights. He must have had no more earnest conviction of his power than did many people of his time, for he cured them by the thousands.

Cagliostro presents himself as one about whom we might say little that is good. He it was who in the middle of the eighteenth century put magic to profit, discovered hidden treasures for gain, developed forgery as a fine art, sold the virtue of his wife to add to his chest of treasure and healed the sick of Europe by mystic means. He is the one character of whom I have read that seems deserving of the gentle offices of the Roman inquisition. It is not displeasing to know that he died in prison following sentence from this court.

The subject of "Magnetic Cures" owes much to Professor Maximillian Hell, of Vienna, whose astronomical observations were interrupted by the electrical sparks that were drawn from the heavens by Benjamin Franklin's kite. The good professor theorized that magnetic forces might have the power to pull diseased parts straight, and the practical application of his ideas resulted in making the lame walk. Here a germ of truth, the magnetized

metal, was combined with professorial suggestion, and the era of magnetic cures began.

Friedrich Anton Mesmer, the Austrian physician, may be regarded as one of the most interesting quacks of all time. In fact, there is room for doubt as to whether he should be spoken of unqualifiedly as a quack. He was a man of excellent general education, and received his medical training at Vienna under such masters as Van Swieten. He became interested in astronomy early in his career, and had strong leanings toward mysticism. He serves as an excellent illustration of the type of man who thinks too much and observes too little. With the advent of electricity, he, like Professor Hell, connected it with his astronomical notions, and, because of the supposed relation of the stars to the lives of men, inferred that it could be turned to use in the cure of disease. Magnets appealed to him as the tangible means of bringing about its application, and his methods met with gratifying success. It was not until he came in contact with the good priest, Gassner, a German clergyman who had demonstrated the efficacy of clerical suggestion in curing disease, that he learned that similar results could be obtained by personal contact without the intermediary aid of material magnets. But magnetic force had formed the basis of his original conception, and he could not relinquish the idea. So he proceeded to evolve an elaborate system of words and ideas to prove that magnetic force was an inherent quality of human flesh, and that the interaction of one personality on another could be made to bring about desired results. Here we have an example of the *doctrines* that have been built up by these queer and freakish thinkers, the revival of the doctrine of animal magnetism. Its author rapidly persuaded himself and others that his personality was endowed with a lion's share of this mystic quality and that he was peculiarly equipped to influence the destinies of other people. There is every indication that Mesmer entered upon the elaboration of his notions with earnestness and sincerity. But it is more than equally certain that the material success which attended his efforts soon led him into the grossest kind of commercial charlatanism. His temple in Paris was sumptuously furnished, varicolored lights were employed to maximum effect, soothing strains of music were continuously in the air, the atmosphere was charged with burning incense and the great healer enhanced the natural magnetism of his body with rich and mystic robes. Controversies raged around him, the medical profession arrayed itself against him, excitement took possession of Paris and extended to distant parts, and the human magnet attracted to itself the lesser human magnets and a greater part of human wealth. After a few years of unprece-

dented power he was literally forced out of Paris with opprobrium and stamped with the epithet of imposter; but it is highly probable that he had developed a convenient cynicism that permitted of the enjoyment of his gains.

Phineas Quimby, one of America's most noted exponents of magnetism as a panacea, holds an interest for us in that there is good reason to believe that he played no little part in directing Mrs. Eddy's thought into the channels that finally emptied themselves of Christian Science slush. This good doctor relied entirely upon animal magnetism or hypnotism in his ministrations, and it is said that his cures were as marvelous as could be desired. As will be seen later, Mrs. Eddy had already proved herself to be a suitable subject for suggestion as a means of producing or curing disease when she consulted Dr. Quimby as a means for relief from "spinal nervousness." She had fallen on the ice in New Hampshire, doubtless landing in the conventional position, and had sustained a disability which in these times is almost specifically produced by street-cars, railroad trains or other corporation agencies. Physicians and surgeons had failed to relieve her, but Dr. Quimby's soothing words and manual rubbings brought her to what she said was "better health than I before enjoyed."

Spiritualism may be looked upon as an offshoot of the doctrine of magnetism, the influence of magnetic personalities simply being extended into the spirit world. As is well known, this movement originated in America, in the home of the Fox sisters of New York, where supposedly unexplainable rappings were given intelligible meaning, and contact with the spirit world established. This led to the day of mediums, peculiarly endowed personalities who, in trance states, did all that one could wish in establishing a liaison between the here and the hereafter. Andrew Jackson Davis was a notorious imposter of this type, but his cures were no less effective than his proceeds handsome. This movement was conceived in fraud, as was afterwards confessed by the Fox family, but Sir William Crookes, Sir Oliver Lodge, Sir Conan Doyle and other "intellectuals" seem to be of the same opinion still. Harsh words rush to mind when men of this type, representatives of science, learning and station, fall for such fanciful notions, but let us be content with repeating that "sweetest things turn sourest by their deeds, lilies that fester smell far worse than weeds."

Christian Science, spoken of as the bastard child of a pseudoscience and an unholy religion, owes its inception to the reactive phenomena of an hysterical disposition. Mary Baker was born and reared in enlightened and refined surroundings, and she attracted attention in childhood by her precocious thinking about

religious matters. The idea of predestination seemed to have oppressed her by its hopelessness, and she cast about for ways out of the difficulty. In early life she suffered from a fever which subsided shortly after she had prayed for relief under the instruction of her mother. This episode deeply impressed her, and assumed even deeper importance upon retrospect when, in later life, she connected it with other *experiences*. Her deliverance came when, in 1866, at 45 years of age, she obtained relief from spinal nervousness through the ministrations of Phineas Quimby and the fervor of her prayers. She says that the experience brought her to "the scientific certainty that all causation was mind." Predestination became impossible when God was demonstrated to have an appeal-reaching nature, a sympathetic ear to human suffering, and a willingness to change his mind, to substitute health for ill health upon request. With fanatical generosity she proceeded to share her discovery with others, and her enthusiasm and undoubted sincerity, combined with her ability to dress her ideas in pious and semi-scriptural phrases, succeeded in establishing an absurd system of philosophy and healing so firmly that a considerable portion of mankind seems destined to follow it forever. It is useless to point out the errors and inconsistencies of Christian Science to properly balanced minds, but it is interesting to remember that "cures" in infinite number have been effected by it; the fact that many real cures have been prevented by it is certainly of less interest, if of more importance.

John Alexander Dowie was a canny Scot who found a fertile field for his pretensions as a personal healer in America. He, too, combined variety in religious thinking with suggestion in the cure of disease. He proclaimed himself to be "Elijah the Restorer," and great numbers were gladly restored by him. He built churches and cities with the proceeds from his cures, and reigned as dictator among his citizens, imposing upon their civic liberties as well as upon their freedom of thought. But great was his fall, for he was finally expelled from his own church and city on charges of fraud, tyranny and polygamous tendencies.

Hahnemann's homeopathy is just now taking its last dying gasps after more than 125 years of imposing its absurdities upon mankind. But it, too, has had its cures by thousands, and, in spite of the pedantry and falsity of its doctrines, it doubtless saved many poor patients a nauseous dose of medicine at the hands of the regular physicians. It is supposed that Hahnemann was stimulated to his work by the promiscuous drugging which was generally practiced in the treatment of disease, and his millionth part of the common doses was doubtless a great boon to patients. His plagiarized

slogan, "similia similibus curantur," his provings, potentizings and dynamizing of drugs and his other weird words and phrases seem to have successfully mystified the human mind, and were doubtless important factors in the efficacy of his treatments. Even such satire as Bishop Doane's did not laugh it out of court:

> Stir the mixture well
> Lest it prove inferior;
> Then put half a drop
> Into Lake Superior.
>
> Every other day
> Take a drop in water.
> You'll be better soon,
> Or at least you oughter.

F. Matthias Alexander, of Australia, is to be mentioned in passing because his system of physical and mental culture has proved such a boon to the trained minds of university professors. Walsh gives some extremely amusing testimonials from college professors concerning this quack. He quotes one of the professors as follows:

> He does not have to undress you or ask you what is the matter with you, or establish your anamnesis. Your obviously faulty posture and movements immediately strike his keen, experienced eye. He sees the beginnings of cancer, appendicitis, bronchitis, tuberculosis, etc.

Walsh also says that the "Introductory word to this work in which appendicitis, cancer, tuberculosis, etc., are cured by means of breathing exercises and 'conscious control' of the muscles, was written by one of the best educated professors in this country who is the head of the department of philosophy of one of our most important universities." God! What a travesty on the word philosophy.

In connection with the easy mark which is often afforded by learned men for quacks, Bishop Berkeley presents an amusing picture of such a man. He devised a cure of his own, and magnanimously gave it to his fellow-man. This philosopher, religious worker and missionary among the American Indians discovered the versatile healing power of tar water. He simply mixed a gallon of water with a quart of tar, allowed it to stand for forty-eight hours, and poured off the supernatant fluid, thus obtaining a remedy which he recommended for "gout and fever, coughs, pleurisy, peripneumony, errysipelas, asthmas, whether it come from the heart or kidneys, indigestion, hysterics, mortification, scurvy, and liver diseases." We might be thankful that the clergy have given up some of their former tendency to cure the body, and we might hope that their efforts to save the soul are based on somewhat more rational grounds.

Andrew Taylor Still has been credited with sincerity in his founding of the cult of osteopathy. He was a fairly well-educated man, a physician and one who devoted much of his spare time to the observing of plants and animals. It would seem that he was thrown off of a level footing, in the mental sense, by the death of three of his children from spinal meningitis and was led to search for some new method for the cure of disease. Osteopathy was the product of his musings. Nothing could be more irrational than the ideas around which this cult was built, but it worked and is still working. The suspicion of cupidity in the founder is aroused by his own statement that he had been accused of being crazy by his clerical brother, but that he later won him over when he demonstrated that "there was money in it."

Chiropractic is of too recent origin to demand much comment. B. J. Palmer, D.C., Ph.C., the founder and propagator of the cult, states that the first chiropractic adjustments were given by his father, D. D. Palmer, in 1895. Since then innumerable spines have been adjusted and cures wrought, as witness the testimony before our legislatures. Until very recently chiropractic concerned itself entirely with the matter of cures, this being a common trait of practically all quack systems, but in the past year the fertile brain of Palmer has devised an instrument, the neurocalometer, which makes diagnosis easy and mechanically accurate, pointing out unerringly the nerves that have their vital capacities interfered with by pressure. It is estimated that this new discovery will net Palmer a great deal of money from his disciples, a direct tax which will unfortunately be passed on to the gullible public.

Albert Abrams was a queer freak. He must have been a manic type with an overactive and superficial mind. He received an excellent medical education, and seems to have done well enough in the practice of medicine for a time. But a cerebral switch was left open, and his mental machinery ran off the track. This freak differed from the others in that diagnosis was given a prominent place in his system. It is charitable to think that this deviation from the custom of the usual quack may have been responsible for so many of the regular medical profession swallowing Abrams's bait, hook, line and sinker. It seems to have mattered as little to them, as to the poor seekers after health, that he coined unintelligible words and that his writings evidenced gross misunderstanding of such terms as watts, ohms, amperes and volts. It is rather surprising that this scheme should have begun to wane so soon.

Walsh, in his very entertaining book on cures, classes Freud and psychoanalysis along with the type of quack of whom we have been treating. There is doubtless much to be said in favor of this

idea, and the probabilities are that as time goes on we shall recognize more complexity in Freud's expressions than truth in the complexes which he purports to describe. Certainly his cures have been forthcoming, but with equal certainty a tremendous amount of mental obfuscation has resulted.

In this day of patented medicines, we should not fail to mention the successes which have attended similar agencies in the past. Weapon ointment had much to commend it. The salve was applied to the weapon which had inflicted the wound, and the wounded was spared meddlesome and painful handling. Not even this backhanded compliment can be paid to most of the others. Theriac, the preparation which contained sixty-four ingredients, tar water, mummy pills, rattle-snake poison and countless other buncombes have proved as efficacious as have tanlac, Lydia Pinkham's Vegetable Compound, Peruna and Doan's Kidney Pills. It was the success of these remedies which caused Lowell to exclaim, "What is the need for an Aladdin's lamp when palaces can be built out of patented pills?"

Treatment vs. Diagnosis

Sentient beings must pay the penalty of pain for pleasure. The capacity to experience the latter carries with it the necessity for feeling the former. So we might say that suffering entered the world with consciousness. With the advent of thought means for the relief of suffering were immediately sought. As some one has said, it is an inherent instinct in man to believe that relief from suffering is an attainable goal. Consequently, the attention of all mankind is readily attracted by subjects that deal with the preservation and restoration of health, but especially with deliverance from discomfort. However, it is interesting to observe how lacking in the inquiring spirit this interest is. In this subject, of all others, we seem to be intensely practical, caring for nothing but results, and wishing, even, not to be bothered with the whys and wherefores of our cures' success. A sick man may be likened to a landlubber on a disabled ship at sea; he cares little for the technical skill, or lack of it, with which the sails are manipulated. It is any port in a storm for him, and any means of getting there. A physician, looking sufficiently far ahead to recognize the greater usefulness of proper thinking, might approve Dr. Halsted's statement that he would rather be wrong with a reason than right without one, but it is easy to understand that the patient would strongly subscribe to the contrary view. Thus it is that empirical methods for the cure of disease have taken little heed of the matter of diagnosis, or of determining the underlying cause of the patient's trou-

ble. They go directly to the fountain head of human interest—*cures*. Their discoveries are good for all troubles, so why should they concern themselves with differentiating different kinds of trouble? This train of thought certainly seems to meet the demands of the situation, for "age has not withered it, nor custom staled its infinite variety." Abrams proved himself the outstanding exception to this rule. He at least went through the motion of making a diagnosis, and this may have had no little to do with the relatively brief duration of his fantasy. But his cure was omniscient, the specific electrical vibrations all came out of the same machine, adjusting themselves to the peculiar needs of the individual and dispensing "ohms" with a selective intelligence. This should have been general enough to obscure specific thought. But they turned it down! And, why do you suppose? Consider, and see if you do not think that it was due to the effort to introduce a quack system for the *investigation of disease*. This idea of diagnosing syphilis, cancer and tuberculosis from a drop of blood that had traveled thousands of miles was too enticing a thought to escape the attention of well people, and they think a little straighter about health and disease than do those who are sick. Abrams' effort will doubtless serve a good purpose in that a long time will elapse before diagnosis is again given a prominent place in association with new cures.

Effectiveness of Quacks

The effectiveness of quacks, considering for the moment only those conditions which they themselves create, doubtless results, mainly, from the following causes:

(1) A dominant personality in the healer. These people are most often of a forceful type, frequently with a brazen air and a rhinoceros hide, and their fervor of fanaticism or greed permits them to put an enthusiasm into their movements that inevitably sweeps the suggestible part of their fellow-men with them. It is important to bear in mind that, in most instances, the originators of the different cults are actuated by a sincere belief that they have found something that is of real value. They fall into that group who know not and know not they know not. This combination of confidence and blindness gives them a stirring urge to spread their new gospel.

(2) The verbal dress in which they clothe their thoughts is high-sounding and seems to be effective. It is very difficult to understand how the words and phrases that have been created by these impostors could fool intelligent persons, but we have seen that professors, clergymen and physicians all fall for them. Volumes have

been written about one word in the battle-cry of homeopathy, an apparently earnest effort to determine whether Hahnemann intended to vary the dictum of Paracelsus to the extent of changing an "a" to an "e" in curantur. Bishop Berkeley philosophizes tar water into universal efficacy "with words of learned length and thundering sound"; Alexander satisfies our college professors that "he actually remodels the body as a sculptor models the clay, gives one a fresh and discriminating muscular sense which not only does away with distortions and expensive strains, but reacts upon one's habitual moods and intellectual operations"; and practically all the others have mystifying words surrounding their practices. Two authorized definitions of healing sects will serve to illustrate this point. The first is the definition of natureopathy appearing in the statute books of the state of Connecticut. It is as follows:

For the purposes of this act, the practice of Natureopathy shall be held to mean the practice of the psychological, mechanical and material sciences as follows: The psychological sciences such as psycho-therapy; the mechanical sciences such as mechano-therapy, articular manipulations, massage, corrective and orthopaedic gymnastics, neuro-therapy, photo-therapy, hydro-therapy, electro-therapy, thermo-therapy, physio-therapy, chromo-therapy, vibro-therapy, concussion, pneumato-therapy and zono-therapy; and the material sciences such as dietetics, histilo-therapy and external application.

They might have included under the material sciences the license to extract shekels.

The nimble-witted Dr. Palmer speaks of chiropractic in the following terms:

Chiropractic is a name given to the study and application of a universal philosophy of biology, theology, theosophy, health, disease, death, the science of the cause of disease and the art of permitting the restoration of the triune relationship between all attributes necessary to normal composite forms; to harmonious quantities and equalities by placing in juxtaposition the abnormal concrete positions of definite mechanical portions with each other, by hand; thus correcting all subluxations of the spine, atlas to coccyx inclusive, for the purpose of permitting the recreation of all normal cyclic currents, through nerves, that were formerly not permitted to be transmitted, through impingement, but have now assumed their normal size and capacity for conduction as they emanate through the intervertebral foramina—the expressions of which were formerly excessive or partial lacking—named disease.

It must take a man of ingenuity to use so many words and fail to make sense out of them. However, these expressions seem to satisfy the minds and cure the bodies of our citizens in this, the twentieth century.

(3) The disciples of the master quack, as well as the masters themselves, after they have tasted of material success, stoop to cheaper means in selling themselves and their wares to the credulous public. Lurid testimonials of cures that have been accomplished, newspaper advertisements of an enticing nature, impressive de-

meanors and all tricks of the trade are carefully studied, and the whole used to the best advantage.

(4) The quack not infrequently becomes the dupe of his own pretensions, and his successful handling of suggestible subjects too often persuades him that he has been chosen by God to deliver mankind from the bondage of disease. When this change of personality comes, and the retrospective falsifications of memory follow, his power as a healer is greatly enhanced, and his arrogance and assurance proceed hand in hand.

Receptiveness of the Public

The success of any human endeavor depends upon human receptiveness to it. The above review and our daily observations show plainly enough that people of all times are peculiarly receptive to any idea relating to the cure of disease. It is interesting to inquire as to why this is true.

In the main, the situation may be summed up by the statement that when the sickness comes in the judgment flies out. Introspection and subjective thought are notoriously productive of unsound reasoning, and physical disability is immediately productive of this type of thought. Even trained physicians do not escape its ravages. All of us have had minor illnesses which have received from us the gravest interpretations. And the more we think under such conditions, the further wrong we are likely to go. In contrast to learning, too much thinking about such matters is a dangerous thing, for thinking, as well as conscience, is prone to make cowards of us all.

The fallacies resulting from this type of thinking are typical examples of Bacon's "idols of the cave." In this state of mind mankind may be depended upon to be consistently illogical and is an easy target for any suggestion that may be aimed at him. Hippocrates recognized this fact in his aphorism to the effect that nature cures the disease while the remedy amuses the patient, and Oliver Wendell Holmes expresses the idea in his own inimitable fashion as follows:

> There is nothing men will not do, there is nothing they have not done, to recover their health and save their lives. They have submitted to be half-drowned in water, and half-choked with gases, to be buried up to their chins in earth, to be seared with hot irons like galley-slaves, to be crimped with knives like cod-fish, to have needles thrust into their flesh, and bon-fires kindled on their skin, to swallow all sorts of abominations, and to pay for all this, as if to be singed and scalded were a costly privilege, as if blisters were a blessing, and leeches a luxury.

In addition to this general consideration, there are two specific ones that tend for something more than simple receptiveness on the part of those who patronize medical fakirs. The partisan attitude

of these patrons is a striking phenomenon. It is not uncommon to find some of our better citizens, not content with availing themselves of the services of the quack, but urging others to do so and busying themselves to bring about a legal recognition of the new system of healing. The probable explanation of these activities is that these worthy citizens feel the necessity for justifying their departure from the commonly accepted ideas of society relating to the cure of disease. They are conscious of the need for defense, and their defense reaction leads to aggressiveness. Again, the custom of practically all quacks to demand payment in advance of treatment tends strongly to the success of their ministrations, for no man likes to admit that he is stung, and he has more than a common interest in the success of his venture when his money is in it.

Deficiencies of the Regular Profession

The regular medical profession has contributed its full share to the success of quackery. There are some general indictments that might fairly be levelled at us. We have too often let our theories outrun facts, we have taken up fads and isms with the best of them, we have supplanted common-sense with doctrines, we have put pomp and circumstance above substantial scientific attainment, and we have let our cures make us arrogant: there is almost no practice among those that we are pleased to call quacks that has not its parallel in the activities of our own brethren. Dr. Mayo gave thanks that medical science had advanced to the point where the physician could perform his functions in a sack suit, discarding the added embellishments of a long coat and high hat. But these adornments are still figuratively with some of us in manner, word and action. We have high-sounding phrases, words that obscure or falsely satisfy thought, and we administer drugs and treatments with a gullible satisfaction in their efficacy or with the conscious intention of amusing the patient while nature cures the disease. As long as such practices continue we must face our responsibility in contributing to the success of the irregular practitioner.

Suggestion was long a thoroughly approved medical practice. It may be defined as the act of transferring an idea or mental state to another, irrespective of its truth. Here we are speaking of conscious or purposeful suggestion, and this is the only kind of suggestion for which we need assume responsibility. Suggestion must always play a large part in determining human conduct, but the medical profession need not stultify itself by misinterpreting the phenomena which result from it, or by subscribing any longer to the practice of telling falsehoods as a means of curing disease. But the biggest fool of all fools is the fool that fools himself, and doctors

have a peculiar susceptibility to this type of fooling. Hypnotism, the violet ray, the electronic phenomena, innumerable worthless drugs and a host of other matter could be mentioned to show how thoroughly members of the medical profession can be fooled. However, it is not being fooled that we are warring against now, but fooling. Not so very long ago I was shocked to hear a young physician, at a medical society meeting, say that doctors could not afford to be entirely honest with their patients. It is disappointing to hear a reactionary expression of this character uttered by a young man, for it brings to mind the possibility that the custom of fooling patients, the great barrier between the public and full confidence in the medical profession, is to stand for some time to come.

Ignorance among doctors is another factor for the success of quackery. In this day of thoroughness in medical education it would seem impossible that lack of information could assume a prominent rôle among us, but such is too often the case. The completion of a college course, a medical one in particular, does not produce an educated man. The simple foundation is laid upon which to build. The finishing of the structure depends upon continuous activities as a student, and, unless these constant touches be applied, the unfinished parts are likely to rot. Dr. Barker has said that the internist who sleeps for more than eight hours is apt to fall behind; and there is not good reason for admonishing only one group. On what other grounds than ignorance can we explain a medical man's advice against typhoid vaccination, his use of salol as an intestinal antiseptic, his ready prescribing of proprietary remedies or advice to a diabetic that milk may be taken in unlimited quantities? We can not blame people for rushing from such practices and seeking assistance elsewhere.

As Selden says, "no man is the wiser by his learning." There is an inherent quality of mind, the capacity to discriminate essentials from non-essentials, the faculty of estimating the value of new ideas and proposals or the ability to decide between truth and error, the great mental function of judgment that seems to be possessed by all too small a portion of mankind in general, and which does not seem to be developed by even extended efforts at education and training. Physicians show this deficiency as plainly as others. Possibly its failure in them is more striking than in other professional men, for there is a distinct tendency on the part of patients to aggrandize a physician, to ascribe to him almost supernatural qualities of information and judgment, and, when their ideas meet with disappointment, they are likely to generalize the shortcomings of the individual to the profession which he represents. A fallen idol is contemned, and the medical profession has

to pay the price of having suspicions of inefficiency directed at it in return for the very veneration which the individual doctor commonly enjoys. We should not quarrel with our fellowman for this decision; we should busy ourselves in teaching him what to expect from the medical attendant of his choosing and lead him to know that, failing to find it in one, he may safely expect it in another. In other words, the public should be taught to look to medical science for assistance and to regard the individual practitioner as the fallible servant of this great organization.

Even the conscious efforts of the medical profession to protect the public from incompetence in its own ranks and from the ravages of the irregular practitioner, have done no little to arouse a sympathetic interest in the latter. For about ten years, ending in 1873 when Texas passed the first medical practice act of this country, Dr. N. S. Davis tirelessly advocated the passing of laws which would require proper qualifications in those who were to practice medicine. Since that time every state in the Union has passed similar laws, and our medical examining boards are supposed to stand as an effective barrier between the public and inadequately equipped physicians. But, in the very nature of things, these boards are made up of physicians, and when they declare that representatives of the quack cults of one kind or another are not properly equipped for practicing the healing art, they give cause for the raising of the cry of persecution, discrimination and fear of competition. The quack and his patron use these ideas to full advantage.

Is there Deliverance from the Quack?

At first blush one is inclined to say that the quack is destined to be with us always. The instinctive desire of man to seek relief from suffering, his lack of judgment when in pain, and his ready belief in the *experience* of those who have been cured by any means whatsoever make it almost certain that irrational and even unscrupulous systems of healing will always have a vogue.

We have seen that education does not equip a man to think in a discriminating way when he is sick. Louis XI believed in his Gallioti who foretold his destinies, Queen Anne entrusted her eyes to William Read and knighted him for his frauds, George II yielded his body to the ministrations of "Spot" Ward, Napoleon consulted the pythoness Lenormand, Bishop Berkeley had an abiding faith in tar-water, Alexander preys upon the undeveloped and underused bodies of our college professors, and we frequently hear of respected citizens being cured by the osteopath, the chiropractor and the electronic wave.

The law seems powerless to stop the irregular practice of medicine. Laws we have a-plenty. But for some reason they do not

work. It is said that in some states, where chiropractic is specifically outlawed, the chiropractor does his most flourishing business. We see the quack openly defying the law, declaring its administration wrong and continuing his activities in spite of it all.

There is one hope of deliverance. Just as scientific chemistry banished alchemists from the face of the earth, medical science is capable of routing the host of imposters that are now barking at its heels. But medical science must, like chemistry, become impersonal. No one thinks to-day of a chemist as other than a student or investigator of his science; the chemist dwindles into insignificance in comparison with the colossal size and substantiality of chemistry. So the physician must be subordinated to the great subject in whose name he is working. The public's attention must be directed to medicine and its truths, not to doctors and their errors. The test of medical science is the prevention of disease. Smallpox, typhoid fever, the plague and many other diseases have had their ravages checked by the application of exact sciences, chemistry, physics and biology, which, because of the mode of their application and the purposes for which they were used, have been grouped under the collective term of medical science. It is this shrine at which we must worship. We must show the people our god, and ask them to see in us his servants, subject to error.

Still our *cures* rise to plague us. It is hard to meet with success and still be humble, and cures must fall to the lot of all physicians, for nature's inevitable tendency is toward repair. Here the humble priest must take great care lest he become a god, for, if he should, his services to the cause are lost, and he is likely to be cursed by the very power which he formerly served. The cure of disease can never be advanced to the position of exactness that is to be attained by its prevention. In many instances, physics, chemistry and biology have yielded us specific weapons with which to wage specific battles, but in many of the problems presented by suffering humanity we must still depend upon less exact means for their solution. The psychoneuroses present the greatest pitfall. Here is the serpent that tempts us away from our salvation. The difficulties here can readily discourage us; the successes can with greater readiness lead us to false conclusions and arrogance. Our protection lies in rigorous honesty, the use of persuasion rather than suggestion in the handling of these patients and a clear appreciation of psychological processes when they show themselves for good or bad. The regular practitioner must follow Polonius's advice:

> This above all: to thine ownself be true,
> And it must follow, as the night the day,
> Thou canst not then be false to any man.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

SUNSHINE FOR BRAINS

It has been known for some years that the ultra-violet rays, whether they come from the sunlight or the mercury-quartz lamp, will greatly benefit and often cure children crippled by rickets or tuberculous joints. It is now found that light treatment not only betters their bones and improves their general health, but also brightens their brains and sweetens their dispositions.

A class of boys from the London slums who were taken to the garden of a private house on Clapham Common, where they studied and played all day long, attired in "very short shorts and no shirts," showed at the end of six weeks that even such feeble sunlight as London affords had increased their mental capacity and alertness as well as their appetites.

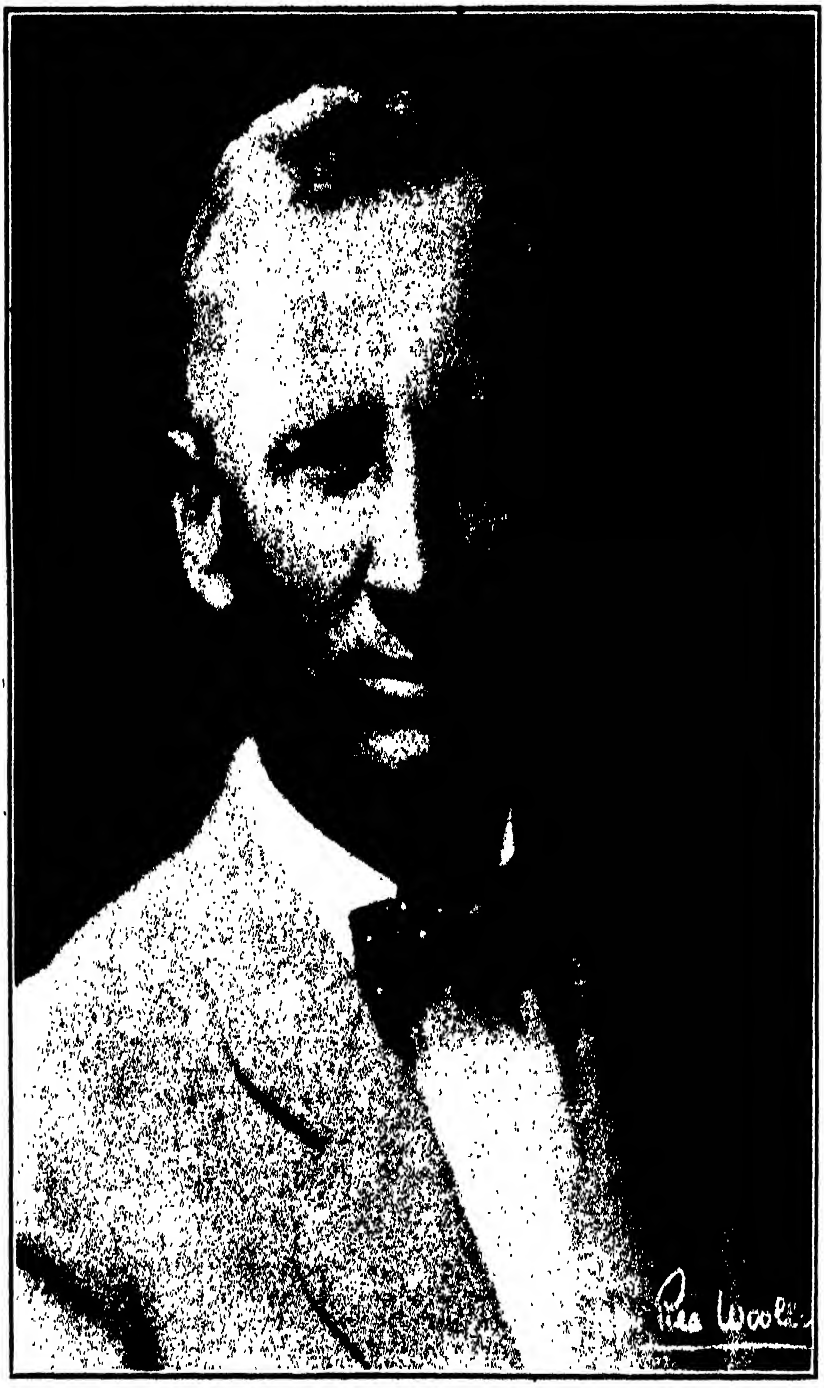
A comparison of the results of mental tests made in the special schools for physically defective children in London with those made on the children who had taken the light treatment at the Lord Mayor Treloar Cripples' Hospital at Alton showed a marked superiority for those who had the advantage of the sunshine. Both groups of children were naturally retarded on account of their disease, but the mental retardation of the London children was on the average 1.95 years, while that of the Alton children was 1.14 years. Both groups were about the same age, 11 years, and the London children had had more schooling.

Sir Henry Gauvain, superintendent of the Treloar Hospital, in reporting these results is careful to add:

> It is not our object to aim a blow at the solidly founded theory that intelligence is innate and can not be increased. It is probably quite indisputable that an individual's amount of mental energy is fixed and unalterable. But it is unalterable in the same way that the maximum power of an engine is unalterable. An engine of a maximum of 40 horsepower can by no trick be made any more powerful. But the ways are legion whereby it can be made less powerful—a dirty sparking plug, a faulty magneto, dust in a delicate piece of mechanism—any of these things, and many others, may reduce its power far below 40. It is suggested that the case is no different with mental energy.
>
> We advance the suggestion, which further investigation may confirm or disprove, that ultra-violet light, shown to be an important factor in effecting tissue change, may thus improve the nutrition of the grey matter of the brain and in this way increase the output of mental activity which we claim follows judicious exposure to light.

A more exact test was made at Alton on a ward containing 20 small children all afflicted with tuberculous disease of the spine, and therefore bound immobile to their beds. The diet and treatment of all were the same, but 10 of the children were given systematic treatment with artificial light. Sir Henry Gauvain reports:

> While the physique of those receiving light treatment showed improvement as compared with the others, the effect on the mentality was even more definite. Those exposed to light were markedly happier, more vivacious, more alert, and, I may add, more mischievous.



DR. MAX MASON

PRESIDENT OF THE UNIVERSITY OF CHICAGO, FROM 1908 TO 1925 PROFESSOR OF MATHEMATICS IN THE UNIVERSITY OF WISCONSIN.

M. PAINLEVÉ

PRIME MINISTER OF FRANCE AND PROFESSOR OF CELESTIAL MECHANICS IN THE UNIVERSITY OF PARIS. WHEN DISTINGUISHED MATHEMATICIANS ARE HEAD OF THE FRENCH GOVERNMENT AND PRESIDENT OF THE UNIVERSITY OF CHICAGO, THERE MAY BE SOME QUESTION CONCERNING THE COMMON BELIEF THAT MATHEMATICIANS ARE NOT COMPETENT IN PRACTICAL AFFAIRS.

THE TWO HUNDREDTH ANNIVERSARY OF THE RUSSIAN ACADEMY OF SCIENCES

ON THE LEFT, LUNATCHARSKI, PEOPLE'S COMMISSIONER OF EDUCATION; DR. SERGIUS VON OLDENBURG, THE ORIENTAL SCHOLAR, PERMANENT SECRETARY, AND ALEXANDER PETROVIC KARPINSKI, PROFESSOR OF GEOLOGY, PRESIDENT OF THE ACADEMY.

They would often laugh and sing and appeared to be overflowing with animal spirits, while their fellows remained silent.

So, if any parents or teachers find their children are not mischievous enough, they may liven them up a bit by letting a little sunshine in. But not too much or too long at a time. Interrupted and periodic exposure to solar rays is superior to continual treatment. Five or ten minutes at a time at first, gradually increasing so as to produce tanning without burning. And remember that window glass is opaque to the short rays that are wanted. So is clothing, except the very thinnest. Artificial silk, rayon, is more permeable to these rays than natural silk, but even lightest fabric of artificial silk will cut off more than half of the ultra-violet rays. Though it be the brain that one wants to stimulate, "direct action" is dangerous. Hats or eye-shades are usually needed.

Every one who has dabbled in photography knows how variable sunlight is in its proportion of the short waves that affect a sensitive plate, and the same is true of a sensitive skin. Ten minutes of sunning will sometimes raise a blister, and on another day when the daylight seems equally bright one can stand an exposure for hours without blushing or browning. A photographic exposure meter or strip of sensitive paper can serve as a test of the actinic and therapeutic intensity of the light. On account of the variable and uncertain character of sunlight, hospitals often prefer to use the rays given off by the mercury-quartz or carbon arc lamps where the dose can be definitely regulated.

THE TWO HUNDREDTH ANNIVERSARY OF THE RUSSIAN ACADEMY OF SCIENCES

PROFESSOR STEKLOFF, THE MATHEMATICAL PHYSICIST, VICE-PRESIDENT OF THE ACADEMY, WITH DR. C. V. RAMAN, PROFESSOR OF PHYSICS AT THE UNIVERSITY OF CALCUTTA.

COMMERCIAL AVIATION

ABOUT 30,000,000 miles have been flown in regular commercial air service throughout the world, according to a progress report of the survey now being made jointly by the U. S. Department of Commerce and the American Engineering Council.

This distance has been covered under widely varying conditions, over land and water, forests and mountains, by day and night, it was said by Professor Joseph W. Roe, director of the field staff of the joint committee on civil aviation, and head of the Department of Industrial Engineering in New York University, by whom the report was authorized.

This accumulated experience, according to Professor Roe, affords data for comparing the development and present status of civil aviation in this country and in Europe, as to growth and character of service, safety, reliability, financial aspects, government relations, etc. It also gives information on the conditions covering air transport, airways and the industrial use of airplanes as in agriculture, forestry and surveying.

Professor Roe favors a federal air law providing for government, supervision of air transport, and indirect aid to commercial aviation, not necessarily in the form of subsidies.

The Department of Commerce and the American Engineering Council are making a study of civil aviation and gathering data which will be of value as a basis for constructive legislation and for guiding investment in this field.

Information, supplied by foreign attachés, aviation officers, engineers and operators is being brought together covering all the regular air services

THE TWO HUNDREDTH ANNIVERSARY OF THE RUSSIAN ACADEMY OF SCIENCES

PROFESSOR SERGIUS VON OLDENBURG, PERMANENT SECRETARY OF THE ACADEMY, WITH THE TIBETIAN SAVANT, HAMBO-ALVAI-DARULOV, REPRESENTATIVE OF THE DALAI-LLAMA.

throughout the world. The study deals with the commercial operation of aircraft, as distinguished from manufacture, and will not touch on military or naval flying.

The report will cover also the world experience in governmental relations with civil aviation. Every foreign air line is heavily subsidized. This does not necessarily mean that American air lines should have subsidies.

Conditions here are more favorable for commercial aviation than abroad, but it can not even hope to succeed without those indirect aids which have been extended to land and water transportation throughout our entire history.

Few realize the extent of such aid, which amounts to about $200,000,000 for the current fiscal year 1925–26 and covers such items as coast and hydrographic surveys, light-house service, weather bureau, river and harbor improvements and rural post roads.

The establishment of aids such as airways, beacons, airports, meteorological and radio services is only applying to air transport the policy long

followed with the older forms of transportation, and without which they could not operate.

A second phase is air legislation. We have as yet no federal air laws and no supervision of air transport. Any inexperienced pilot with any second-hand plane, who can induce a passenger to go into the air with him is free to do so, a condition unthinkable at sea.

There should be a federal air law placing air transport under such proper government supervision as will insure safety. It should be general in character and flexible enough to allow adjustment to the changing conditions of a rapidly developing situation.

It should conform as far as possible to the International Convention for Air Navigation, which is the basis of the air laws of all countries. In Canada such a law has been in operation for five years and is giving general satisfaction.

The survey in hand is gathering the experience of other countries with their air laws to aid in the formulation of similar legislation in this country.

A complete report on the survey, the first of the kind to be attempted either in this country or abroad, will be presented to the Administrative Board of the American Engineering Council at a meeting fixed for October 29 and 30 at Columbus, Ohio.

The chairman of the committee on civil aviation is J. Walter Drake, assistant secretary of commerce, and other members are: Dr. W. F. Durand, president of the American Society of Mechanical Engineers; Professor E. P. Warner, Massachusetts Institute of Technology; L. K. Bell, Washington, former traffic manager of Air Mail, and C. T. Ludington, Philadelphia, general aircraft operator. Working in the field with Professor Roe are J. Parker Van Zandt, U. S. Air Service, who has recently made an extensive study of civil aviation abroad, and Professor Alexander Klemin, head of the aeronautical engineering course in New York University.

THE TRANSMUTATION OF MERCURY INTO GOLD

WHAT appears to be increasing success in the effort of German science to transform mercury into gold is reported in Cothen advices to the American Chemical Society.

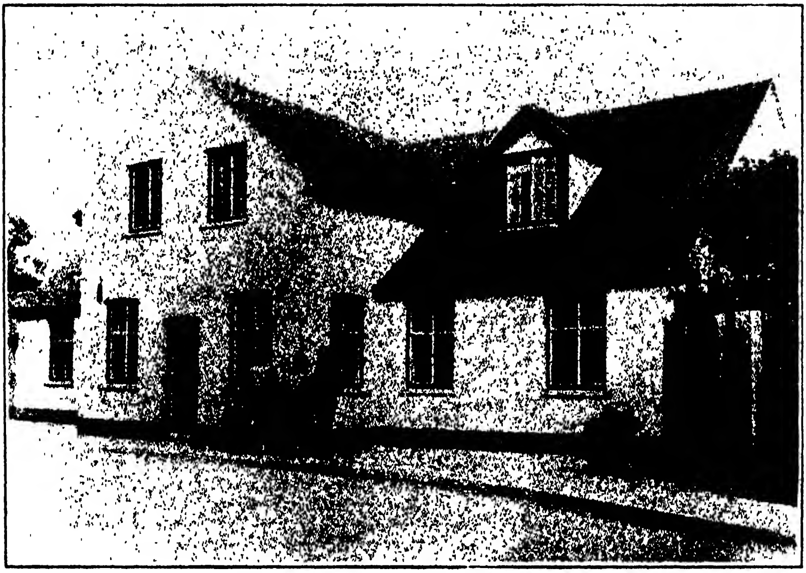
In one year, these advices state, ten thousand times as much gold has been produced from the same quantity of mercury through the experiments carried on by Professors Miethe and Stammreich.

Gold has also been obtained, it was said, at the Siemens Works in Berlin by bombarding mercury surfaces with electrons in extremely high vacuum.

The work of Miethe and Stammreich, it was stated, is dispelling the doubt that existed among eminent German chemists, among them Fritz Haber, internationally famous for his development of synthetic ammonia, a large factor in German war plans. Attempts to derive gold from mercury in the United States by the same methods have failed.

The message to the American Chemical Society from its Cothen correspondent says the skepticism which was fostered privately and publicly toward the experiments of Professors Miethe and Stammreich on the transformation of mercury into gold dwindled when investigators reported before the German Chemical Society the results of their more recent experiments.

Professor Haber, who previously cherished the greatest doubt as to the accuracy of the experiments, congratulated Professor Miethe and re-



—Henry Miller News Picture Service, Inc.

THE BRITISH MOSQUITO CONTROL INSTITUTE

THE NEW HOME OF THE BRITISH MOSQUITO CONTROL INSTITUTE IN LONDON, ENGLAND, OPENED BY SIR RONALD ROSS, K.C.B., F.R.S. THE BUILDING WILL BE USED TO EXPERIMENT ON CONTROLLING THE MOSQUITO PEST IN THE BRITISH ISLES.

lated how on his world tour he had seen in the laboratory of Professor Nagaoka, at Tokyo, the apparatus with which the latter, later, but independently of Miethe, had likewise obtained gold from mercury, and that he himself could confirm the results by repetition of the experiment.

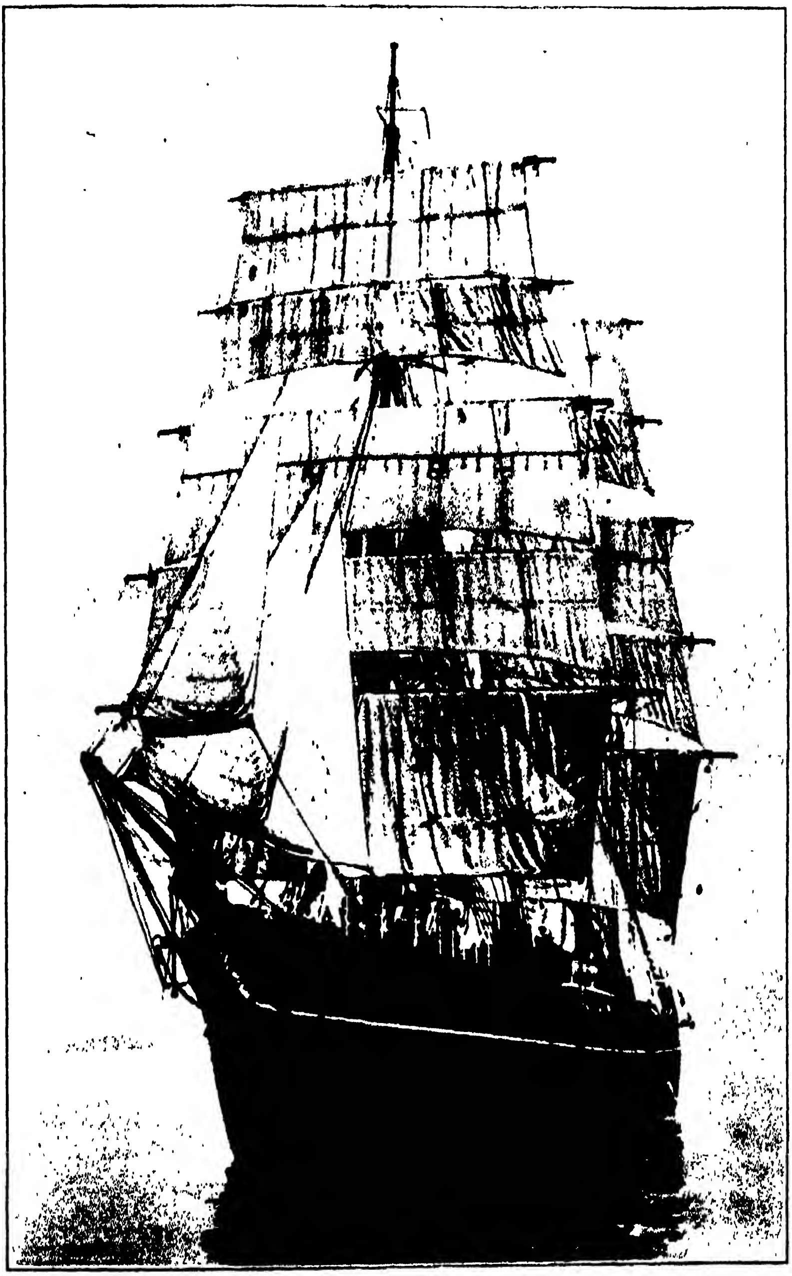
If electrical discharges are passed between mercury electrodes in a dielectric, that is, paraffin, the gold is found only in the mercury atomized in the spark path and at concentrations of gold to mercury as one part to ten thousand, that is, from one kilogram of mercury is obtained 0.1 gram or 100 milligrams of gold.

Up to the time of the first publications, Miethe had obtained one part of gold from 100,000,000 parts of mercury. Thus, in about a year success has been attained in increasing ten thousand fold the yield of gold from the same amount of mercury. Likewise in the laboratory of the Siemens Works in Berlin they have succeeded in obtaining gold after bombarding mercury surfaces with electrons in extremely high vacuum.

It is to be emphasized that all methods thus far applied permit practically complete recovery of the mercury so that the same quantity can be used repeatedly.

Theoretically this is comprehensible even if it is assumed that only the one isotope of mercury, with the atomic weight 197, is subjected to transformation; for the amount of this isotope far surpasses the amounts of gold so far obtained.

The silver-like substance which often appears with the gold, or is formed almost exclusively, arises likewise, according to Miethe, from the mercury. Professor Nagaoka has also obtained, together with gold, a second substance which he described as similar to platinum.



--*Wide World Photos*

"THE DISCOVERY"

LEAVING DARTMOUTH, ENGLAND, UNDER FULL SAIL FOR A SCIENTIFIC VOYAGE TO THE POLAR REGIONS.

HOW TO FIND THE NORTH STAR

Two well known and easily recognized groups of stars, Cassiopeia and Andromoda, furnish an excellent means of locating the North Star, Polaris, in the late fall and early winter evening when they are to be found high in the heaven above the pole. The time-honored method of finding the North Star by means of "The Pointers" in the Big Dipper, though one of the best, can not be used to advantage at this time of year especially by the unfortunate individuals who try to do their star-gazing from city streets. For the Big Dipper now rests nearly on the northern horizon and any obstruction in this direction, such as buildings or trees, conceals it more or less from view.

Cassiopeia, which can be quickly identified by its W-shaped grouping of stars and which is almost as well known as the Big Dipper, is on the opposite side of the pole from the Big Dipper so that when the Big Dipper is near the horizon Cassiopeia rides high in the heavens, and vice versa. To the south of Cassiopeia and about as far from Cassiopeia as Cassiopeia is from the north pole of the heavens will be found the three second magnitude stars in a line slightly concave toward the pole which outline the constellation of Andromeda. The most westerly of these three stars, Alpha Andromeda, is in the northeast corner of the Great Square in Pegasus which lies next to Andromeda on the west. Now let us locate the North Star with the aid of these two groups. Alpha Andromeda, which we have just identified, and Beta Cassiopeiae, which is the star furthest west in the W of Cassiopeia, lie almost exactly in a straight line with Polaris the North Star. Beta Cassiopeiae is midway between the other two stars. Also Gamma, in Andromeda, the farthest east of the three stars in Andromoda, and Epsilon, in Cassiopeia, the third magnitude star farthest east in the W of Cassiopeia, lie in another straight line with the star in Cassiopeia again midway between the other two stars. In other words, two lines drawn, respectively, through the stars at the eastern and at the western extremities of the W of Cassiopeia and of the line of three bright stars in Andromeda meet at the North Star. A little practice will enable one to locate the Pole Star very quickly and easily in this way.

Practically every one knows the Big Dipper in Ursa Major, the Greater Bear, but the Little Dipper formed by seven of the stars in Ursa Minor, the Lesser Bear, is not so well known because it contains fewer bright stars than the Big Dipper. Polaris, the Pole Star, or North Star, at the end of the handle of the Little Dipper is a star of the second magnitude. The two stars that correspond in position to the pointers of the Big Dipper, that is, that lie in the bowl farthest from the handle, are of the second and third magnitude, respectively, but of the four remaining stars two are of the fourth magnitude and two of the fifth, and therefore inconspicuous. Yet it is not a difficult matter to make out the outline of the Little Dipper on a clear night and with its aid we can check up on the position of Polaris by recalling that it is located at the end of the handle.

There are times when we may find it very convenient to be able to get our bearings by the North Star. Every one should know at least one way of locating the important star.—Isabel M. Lewis, *Science Service.*

Vol. XXI, No. 6 Whole No. 123

The Scientific Monthly

An Illustrated Magazine devoted to the Diffusion of Science

Edited by J. McKEEN CATTELL

December 1925

Published by THE SCIENCE PRESS

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THE SCIENTIFIC MONTHLY is the editorial continuation of THE POPULAR SCIENCE MONTHLY, established by D. Appletonand Company in 1872. Under the able editorship of Dr. Youmans it performed for nearly thirty years an important service in presenting the advances of science in a readable form. It led in the advocacy of the doctrine of evolution, publishing as many as a hundred contributions from Herbert Spencer and numerous articles by Darwin, Huxley and other leaders.

During the past twenty-five years under the present editorship the journal has aimed to maintain high standards and at the same time to print articles of interest to the more intelligent part of the general public.

The undertaking is not easy owing to the great development and specialization of science, and to the technical terminology in each field. There is also difficulty because those who have the greatest authority are often unwilling and are sometimes unable to put their results in a form that is interesting and intelligible. It has been said that leading English and French men of science have larger appreciation of the importance of keeping science in touch with literature and life and are more ready to devote their time to this service than is the case in America. It may also be, to judge from the number and circulation of scientific books of general interest, that there is a wider public abroad appreciative of such efforts.

None the less it is the case that neither in France, in England or in Germany is there a journal of the character of THE SCIENTIFIC MONTHLY. It has had the continuous cooperation of scientific men on the editorial side and except for a period in the nineties has earned, even without much assistance from advertisements, sufficient support to defray the cost of publication. But it is obvious that if the support were larger there could be a still better journal.

The corporation of D. Appleton and Company were losing over ten thousand dollars a year on *The Popular Science Monthly* when in 1900 they decided that they were not justified in continuing it. It was worth that much and far more to the public, as the American Museum of Natural History is worth the hundreds of thousands and Columbia University the millions of dollars a year that they cost. But a private corporation can not subscribe indefinitely a large sum for the public benefit.

The weekly journal *Science* was in like manner supported for a time by Dr. A. Graham Bell and Mr. Gardiner G. Hubbard, at a total expense of about eighty thousand dollars. There are perhaps five hundred journals and proceedings devoted to the publication of research work in America, not one of which pays its expenses on a regular business basis.

It would probably be undesirable for scientific journals to be directly subsidized or endowed. Indirectly they are now subsidized by the work of contributors and editors supported by endowed or tax-supported institutions and by subscriptions from public libraries. In so far as they require additional support, it can probably best come through an increase in the number of public libraries subscribing for such journals and by an increase of subscribers among those who may realize the importance of supporting an institution essential to society and its betterment.

The present circulation of THE SCIENTIFIC MONTHLY is 8,500. If this number were doubled it would be possible to pay scientific men adequately for their contributions and to improve the journal in many ways. An effort to increase the circulation should have the support of all those engaged in scientific work, for such a journal contributes in large measure to the diffusion of science and to the interest of the general public in scientific progress; it secures new recruits for science and the better support of scientific research and scientific institutions. The adequate and even generous support of those who appreciate the dominant place of science in modern civilization and national welfare should also be expected.

For some years no advertisements, except on the cover, have been printed in THE SCIENTIFIC MONTHLY, for with a circulation under ten thousand they scarcely repay the cost. Advertisements are, however, resumed with the present issue. Those printed add to the interest of the journal, and if the circulation can be increased to 15,000 or 20,000 they would contribute largely to its support. Readers of the journal can assist by seeing that scientific books, instruments, institutions and all opportunities, materials and supplies that are of interest to readers of such a journal are advertised there, and by corresponding with those who do advertise.

THE SCIENTIFIC MONTHLY has never before used its reading or advertising pages to ask for increased support. But it seems to be as reasonable to do this as in the case of a library, a museum or a university. The journal has no deficit to meet, the circulation now being larger than at any time during the preceding fifty years. But every publication or institution can be made better and more useful than it has been in the past.

No institution should be supported by gifts or by taxation unless it returns to the public more than it costs. Scientific research, the teaching of science, scientific publications, apart from other services, have created wealth immeasurably greater than the modest sums that have been spent on them. The usual way is to give the results to the world and then to beg for money to continue the work. If methods could be devised, such as exist in the fields covered by the patent office and copyright laws, by which scientific work was rewarded in proportion to its value to society, the progress of science would be greatly accelerated to the benefit of the whole world.

In the case of a scientific or other journal there must be a certain circulation to meet the costs of manufacture and a circulation that makes it possible to obtain and print advertisements. When the circulation exceeds these figures, advance is rapid. The second ten thousand copies can be supplied at half the cost of the first ten thousand and advertisements then contribute to the support. The journal can thus be made better, and so will secure more subscribers and more advertisements, and can be made still better. It is a pleasant thought for publishers, in spite of the fact that the process is reversible.

THE SCIENTIFIC MONTHLY has now reached the position where the publishers feel justified in seeking advertisements that will interest its readers, and it is in explanation of this departure that this announcement is inserted on its first regular advertising pages. It is hoped that the circulation will continue to increase in geometrical ratio and that there may be published in the United States a journal that will contribute its part to the diffusion and advancement of science, which it is not unreasonable to maintain is the most important work that can be done for the nation and for civilization.

THE SCIENTIFIC MONTHLY

DECEMBER, 1925

TELEPHONE PICTURE TRANSMISSION

By Dr. HERBERT E. IVES

BELL TELEPHONE LABORATORIES

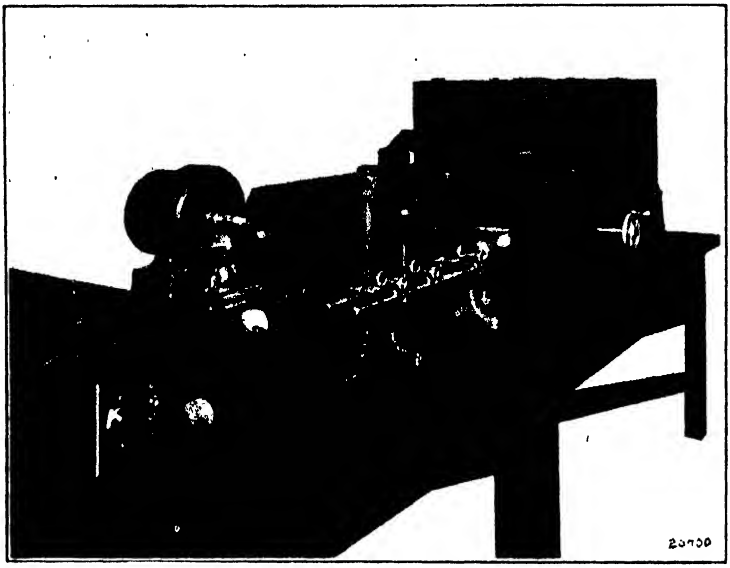
THE picture transmission system which is now in daily commercial operation over the lines of the Bell System is to be distinguished from earlier efforts toward the same end by two features: First, the pictures as received are completely commercial in their character, that is, they are immediately available for all sorts of technical uses, for which they are in fact practically indistinguishable from original photographs. Second, the system is, unlike earlier experimental systems, so worked out that it utilizes without change the existing telephone channels, whether these be wire or radio. The distance to which pictures may be sent is limited only by the distances over which commercial telephone service is available.

The simplest analysis of a picture resolves it into a large number of small patches or elements of varying values of light and shade. A picture transmission system therefore involves first of all some means for analyzing a picture into small elements, or "scanning" it. It involves next some means for communicating a record of the values of these elements to a distant point. It involves finally some means for assuring that the recomposition of the picture elements at the receiving end shall place these in their proper relative positions, that is, some means for synchronizing the sending and receiving apparatus.

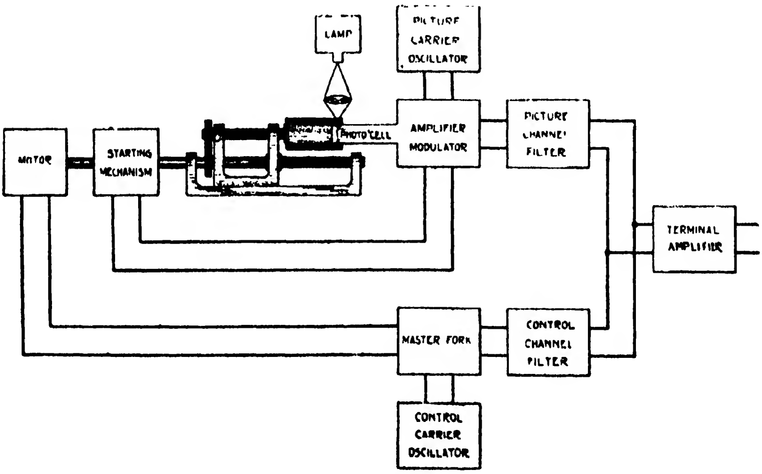
The scanning of the picture is accomplished in our apparatus by first preparing the picture to be sent in the form of a transparent film, which may be bent into cylindrical form; this cylinder is then advanced and rotated by a screw motion so that the scanning light spot traverses the entire film in a spiral. A similar

spiral motion is imparted to the sensitive photographic film upon which the picture is received at the far end.

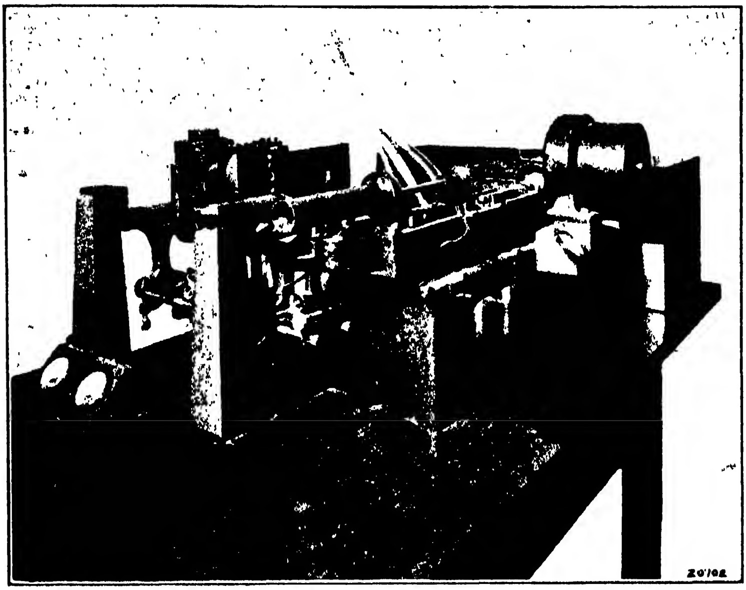
For the purpose of communicating the values of light and shade from one end of the system to the other, we use at the sending end a photoelectric cell. A small spot of light is focussed on the



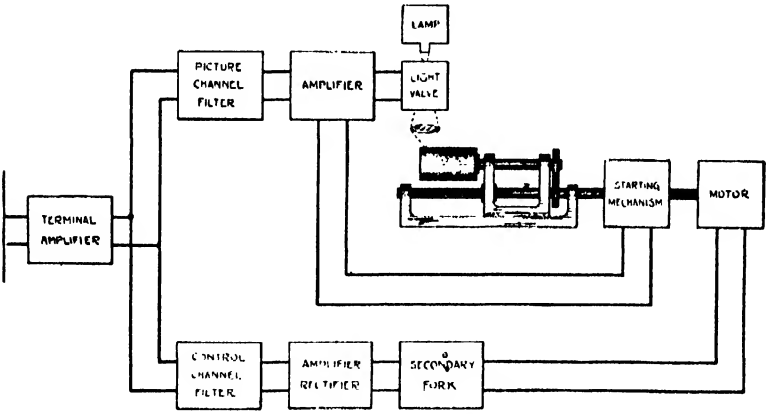
THE COMPLETE APPARATUS FOR SENDING A PICTURE BY TELEPHONE.



THE SENDING APPARATUS IN DIAGRAMMATIC FORM.



THE COMPLETE APPARATUS FOR RECEIVING A PICTURE SENT BY TELEPHONE.

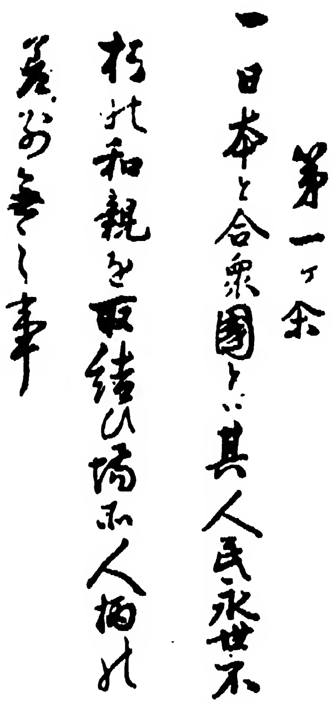


THE RECEIVING APPARATUS IN DIAGRAMMATIC FORM.

transparent film, and, after passing through the films, enters the photoelectric cell. The electric current produced in the cell is directly proportional to the illumination of the cell and follows the variations of light and shade instantaneously. At the receiving end, the electric current which is controlled by the action of the photoelectric cell passes through a narrow ribbon which stands in a magnetic field and by its resultant lateral movement acts as a

A PICTURE OF MICHAEL FARADAY SENT AND RECEIVED BY TELEPHONE.

A MAGNIFIED PORTION OF THE PHOTOGRAPH OF FARADAY WHICH SHOWS THE LINES THAT MAKE UP THE PICTURE.

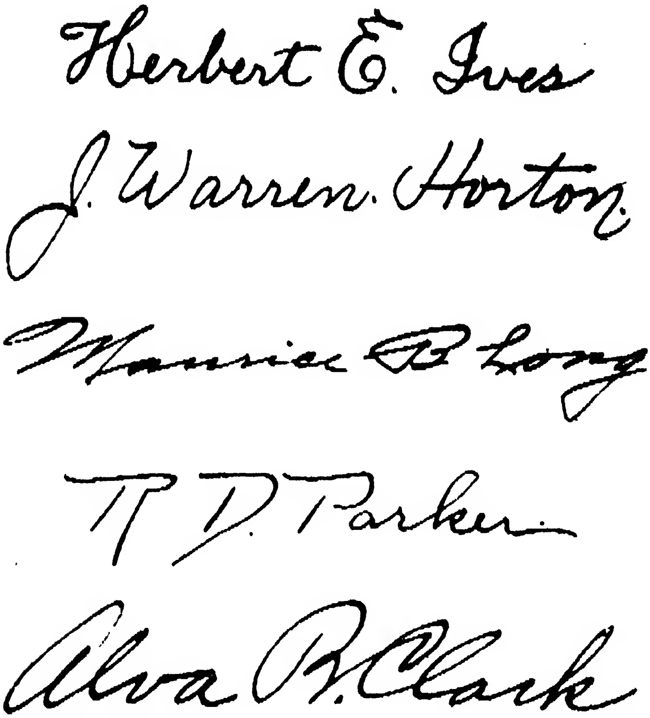

第一ヶ条
一 日本と合衆国とは其人民永世不
朽の和親を取結ひ場所人柄
の差別無之事

FIRST SECTION OF THE JAPANESE-AMERICAN TREATY OF 1853.
This is the only method by which such documents can be quickly transmitted in their original characters.

variable diaphragm in an optical system through which light from an appropriate lamp is passed. The light after passing through this "light valve" falls upon a photographic film and builds up a picture in narrow adjacent strips.

In order to synchronize the rotating cylinders at the two ends of the line use is made of synchronous motors. These are driven by a master tuning fork, impulses from which are sent both to the apparatus at the sending end and to that at the receiving end.

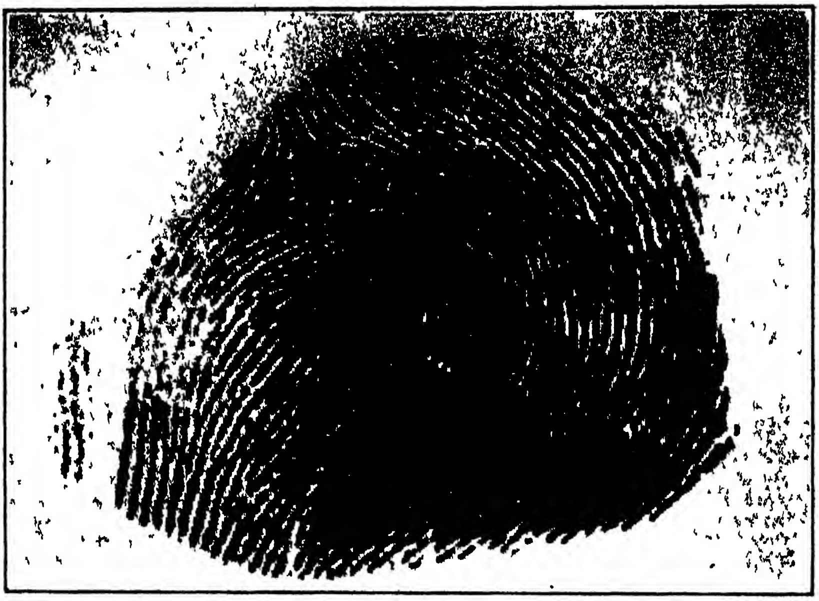
The picture transmission system as just outlined calls for what is ordinarily described as direct current transmission for the picture signal and for a separate communication line to handle the synchronizing pulses. Telephone lines are not ordinarily set up for handling the low frequencies which a direct current picture signal would involve, and it is furthermore uneconomical to use two separate circuits for picture and synchronization signals. For



SIGNATURES TO LEGAL DOCUMENTS CAN BE QUICKLY SENT FROM SAN FRANCISCO TO NEW YORK.

these reasons, both the picture and synchronizing signals are impressed upon carrier currents of voice frequencies suitable for transmission on ordinary telephone lines. The picture signals are carried on a frequency of approximately 1,300 cycles per second, the tuning fork impulses on a carrier of approximately 400 cycles per second. These alternating currents are both sent over the same line and are separated from each other at the receiving end by means of electrical filters, so that the light valve and the synchronous motor each receives only its own proper current.

In the system as now in operation the picture to be sent is placed on the apparatus in the form of a positive film transparency of size 5″ x 7″. The pitch of the screw which provides the rotation and translation of the film is 100 threads per inch. Pictures of this size and grain are transmitted in approximately seven minutes, and transmission may be made simultaneously to a number of



A THUMB PRINT SENT AND RECEIVED BY TELEPHONE, ENABLING LONG DISTANCE IDENTIFICATION OF CRIMINALS.

points, as for instance from Washington to New York, Chicago and San Francisco, as was done at the inauguration of President Coolidge, March 4, 1925. The picture is received as a negative, from which any number of prints can be made by ordinary photographic methods for distribution to newspapers or other customers. By working from wet negatives and using the transparency film at the sending end while still wet, the overall time of picture transmission may be kept below half an hour; the greater part of the time is consumed in the purely photographic operations.[1]

Pictures transmitted in the manner described meet with a number of uses. The widest use at present is in the newspapers, which are now able to show, in a few hours, pictures of events happening at the other side of the continent. A vivid illustration of this use was furnished at the time of the Santa Barbara earthquake, news of which appeared in the New York papers in the evening while the following morning papers had a full pictorial record. Another large field of usefulness promises to be in connection with police identification work, not only in transmission of photographs of

[1] For a more detailed description of the method and apparatus here discussed, see "Transmission of pictures over telephone lines," H. E. Ives, J. W. Horton, R. D. Parker and A. B. Clark, *Bell System Technical Journal*, April, 1925, p. 187.

wanted individuals but of their finger prints. Practical trials have shown that electrically transmitted finger prints may be identified within a few minutes of reception, thus making it possible to identify suspects who, under ordinary court procedure, could not be held long enough for the ordinary methods of communicating this information. Medical information, such as X-ray photographs, electro-cardiograms and other information on which a specialist can make quick diagnosis lend themselves readily to transmission.

The fact that an electrically transmitted picture is a faithful copy of the original, offers a field of usefulness in connection with the transmission of original messages or documents in which the exact form is of significance, such as autographed letters, legal papers, signatures, etc. It would appear that this method might under certain circumstances save many days of valuable legal time and the accumulation of interest on money held in abeyance. For these reasons, it is thought that bankers, accountants, lawyers, and large real estate dealers will find a service of this kind useful.

Advertising material, particularly when in the form of special typography and drawings is often difficult and costly to get to distant publishers in time for certain issues of periodicals and magazines. A wire service promises to be of considerable value for this purpose. Miscellaneous commercial uses have been suggested. Photographs of samples or merchandise, of building sites, and of buildings for sale may be mentioned. The quick distribution of moving picture "stills" which is now done by aeroplane is one illustration of what may prove to be a considerable group of commercial photographs for which speedy distribution is of value.

FOSSIL LOGS AND NUTS OF HICKORY

By Dr. E. L. TROXELL
TRINITY COLLEGE

ALTHOUGH fossilized or petrified wood is common enough, yet the paleontologist is always delighted when he can secure evidence from the plants on the living conditions of the animals of past time. Especially in the Tertiary rocks of the Western Plains is the absence of plant remains notable, not because they did not exist at that time and place, but because they were not often preserved.

In the summer of 1923 I was sent by Professor Lull, director of Peabody Museum, to search for fossil vertebrates in the old hunting ground in northwestern Nebraska; while there I was told of a hill where hickory nuts and pieces of wood were to be found.

The discovery of the site was first made by Mr. Dan Jordan, a ranchman, and the place was visited by the paleontologists, Messrs. Hatcher and Peterson, some twenty-five years ago. In a small group of hills on the school section, about five miles north of the ranch-house of Mr. Tom Plunkett, Harrison, Nebraska, a small basin has been formed which drains out to the northwest. The present contour of the hills cuts through the old strata, laying them bare and exposing in the section the fossil logs and bones, long concealed.

The layers of rock belonged to the so-called Titanothere Beds of the Early Oligocene Epoch and were briefly mentioned by Hatcher[1] in 1900; they contain many logs of silicified and calcified wood, together with the internal casts of hickory nuts, beautifully preserved. At times parts of the shells are found, but these, too, are completely mineralized.

While much has been written about the hackberry seeds (*Celtis*), little seems to have been known about the presence of hickory; it was with especial delight, therefore, that these specimens were rediscovered. In spite of the fact that the nuts vary considerably in size, the further fact that they were found grouped in an area of narrow limits makes it appear probable that they came from a single tree.

Hicoria is well known in earliest Tertiary and again in the Miocene and Pliocene, and fossil nuts have been discovered in the Pleistocene formations. Certain species of the genus have been found

[1] Hatcher, J. B., 1900, *Science*, n. s., Vol. XII, p. 720.

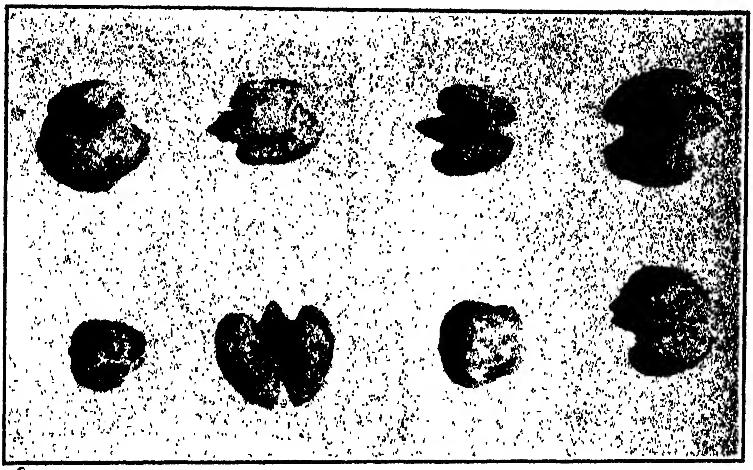


FIG. 1. Fossilized hickory nuts from the Oligocene of northwestern Nebraska. These consist mostly of internal casts, but in some of them parts of the shells are to be seen.

in the coal beds of the European Oligocene, but its widest extent in the past was in the Miocene of Europe and North America. The present-day distribution is limited to southern and eastern North America and to eastern China, but in Tertiary time the hickory existed in Alaska, over all the United States, Greenland, Iceland, Europe and probably in other parts of China as well.

FIG. 2. Hickory logs of Oligocene time. The longer section measured about twelve feet; the shorter one, now in Peabody Museum, was six feet long and more than a foot in diameter.

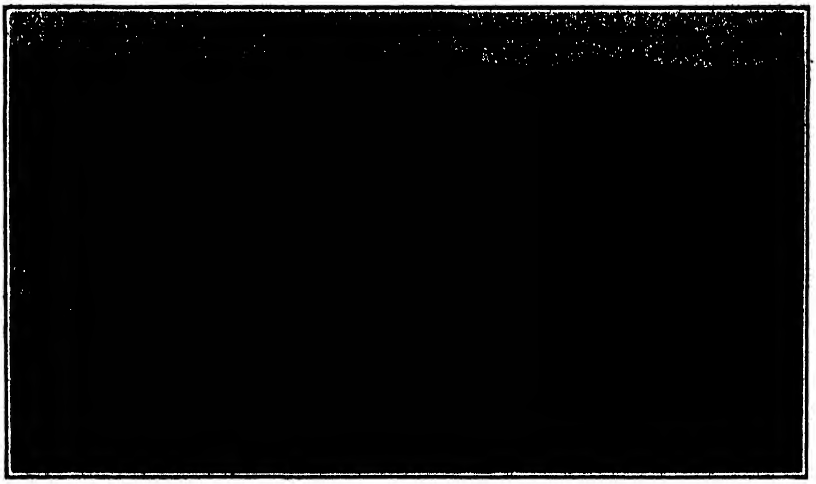


FIG. 3. The basin, in a small group of hills about fifteen miles north of Harrison, Nebraska, where the fossil logs, nuts and bones were discovered.

The hickory, next to the black walnut, is said to be the most costly of our American woods. Because of its hardness, strength, toughness and stiffness it is unequalled in the manufacture of spokes, tool-handles and the like.

Beside the plant remains we were able to secure the fossil bones of a half dozen different animals—*Mesohippus, Trigonias, Hyracodon, Brontotherium, Leptomeryx* and *Hoplophoneus*. We have information here which forces us to modify the widespread conception that the Oligocene was a period of great aridity. However, Berry tells us that the true hickory, as contrasted with the pecan hickory, grows slowly in a temperate, dry soil.

We picture in our imagination, in that corner of Nebraska, the setting of a scene some millions of years ago; the large hickory trees sheltering, on a hot day, an assemblage of odd-toed ungulates, the titanothere, rhinoceroses, the little three-toed horse, together with the deer-like *Leptomeryx;* and overhead a cat lying on one of the branches, ready to pounce down on an unsuspecting victim, to disturb the general tranquility.

THE SERVICE OF STATE-SUPPORTED AGRICULTURAL RESEARCH

By SIDNEY B. HASKELL

DIRECTOR, MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION, AMHERST

Fifty years ago was established the first of our state-supported agricultural experiment stations. These now are the main agencies in the several states for the conduct of research with reference to agriculture. The first appropriation was small—somewhere between three and four thousand dollars. From this small beginning the work has won a large measure of public support. There is now at least one such station in every state, and the total expenditures amount to over ten million dollars annually. Six million of this sum is appropriated directly by the several states. This is a large total. It is important that it be properly expended. This, indeed, is, as I understand it, the problem under discussion to-day —that of striking a balance between the cost of this state-supported agricultural research and the benefits from the investment.

Problems of control of plant and animal disease, of the maintenance and increase of soil fertility, of the breeding of plants and animals make up the major part of the programs of these stations. Not until quite recently have the states enlarged their field to include studies in farm management, on distribution and marketing of farm products, on the purchase of farm commodities and on the manufacture of agricultural products. Even more recently has there been formal recognition of the fact that in the study of social factors influencing farm life there may be a worth-while research investment. For these several reasons, therefore, evaluation of the work of the agricultural experiment stations must be on the basis of the older production projects, some of which are fairly complete, rather than on the newer work which has recently been undertaken.

For my first illustration I can do no better than mention the work of the Iowa Experiment Station with the oat crop. Thirty-five years ago, after some rather disastrous experiences both of the station and of Iowa farmers, the station reported as follows:

> From the frequent partial failures of our oat crops on account of rust, and the rapid deterioration of good varieties which we have imported from the best oat countries, we can draw no other conclusion than that Iowa is not a good oat state.

Compare this depressing picture, portrayed evidently in a moment of discouragement, with a recent publicity statement coming from the same state:

> It is estimated that over 11,000,000 more bushels of oats were grown on Iowa's 5,774,000 oat acreage in 1924 as the result of careful selection of varieties and their adaptability to soil and climatic conditions in the various sections of the state. A recent survey disclosed that about 46 per cent. of our oat acreage in 1924 was made up of four varieties: Iowa 103, which seems better adapted to southern Iowa; Iowar, which develops more favorably under the conditions in the northern counties; Iowa 105, which has a short stiff straw and is recommended only for very rich soils; and Iogren, a medium late maturing variety, which has been outyielding home grown varieties and which is expected to meet with considerable popularity.

Now to a Massachusetts man the figures cited above are rather startling. They represent a single field of oats equivalent in area to the whole state of Massachusetts, allowing nothing for roads or building sites or cities or forests—simply one vast oat field—and this in a state which was believed to be unfavorable to the production of the crop. The present development of this enterprise in Iowa is due in large degree to a vast amount of work done by the station—first canvass of the world to find the most promising varieties, then field tests of these varieties for the purpose of weeding out the poorer sorts. On this as a basis came formal breeding in the attempt to combine the best which the world afforded, to "synthesize" the oat best adapted to Iowa conditions. Supplementing this was work on control of the diseases to which the oat crop is subject, considerable work also on the problem of soil fertility. The final answer is given above. It is beyond me, however, in the short time at my disposal, even to attempt to estimate the cost of the research work which has contributed in making possible continued culture of the oat crop. Likewise it is difficult, if not impossible, to determine the benefit received by Iowa from research of other states and from that of the United States Department of Agriculture or the influence of Iowa research in other oat-growing states.

I present the foregoing as an illustration. I have decided to rest my case on a crop of less total significance, but one with which I am more familiar, and portray in rather great detail the steps which made possible a successful research and then attempt to show the dividends which are accruing and which for years will accrue from such work.

Beginning in the spring of 1918, the Maine Agricultural Experiment Station, in cooperation with the Bureau of Plant Industry of the United States Department of Agriculture, undertook a cooperative research on the transmission of the so-called mosaic dis-

ease of the potato. The disease had been definitely recognized in the state in 1912, had shown itself to be destructive, had come from no one knows where, and had been in the state no one knows how long. A countrywide survey in 1913 showed it to be distributed throughout the country. Research established the fact that the common green aphid serves as the transfer agent for the disease in question. Since the project attained its objective it must be considered a piece of successful research. The fruition of the work, however, is the result of such a long train of studies and experimentation that it is impossible with any degree of justice to give credit to any single individual.

I do not know the money cost of this particular project. In any event it can never be more than estimated, for time clocks are not installed in our experiment stations and few of our workers realize that time cards may be valuable. I estimate the cost to the state of Maine as being between twenty and thirty thousand dollars, extending over a three-year period. Without doubt the federal government contributed a like amount. If so, and putting the proposition on the impossible plane of a mere profit and loss transaction, we have the total of sixty thousand dollars as the cost of this most minute bit of information—that the green aphid, in addition to occasionally injuring the potato plant by sucking its juices, also transmits the virus of a plant disease and carries it over from infected to uninfected and perfectly healthy plants. For the moment let us not quibble over the size of the bill, but assume it to be accurate. Now comes the question—was this information worth its cost?

To answer, I must go back in history and portray those conditions which finally resulted in this particular bit of scientific research becoming the capstone of an attack on a vital agricultural problem. As I do this, remember that the potato is a universally used vegetable food and that its cost is a significant matter to most consumers. Remember also that success or failure with the crop is a vital thing to the nearly three million farmers who grow the potato. Do not forget that for every acre of potatoes grown in this country—and annually between three and four millions of acres of land are cropped to this vegetable—there is an investment of human energy to the extent of at least five full working days. In many cases the time investment is much greater. All important is it to both producers and consumers that this tremendous investment be capitalized to the full.

The first scene in our drama is thirty-seven years ago, when two of our agricultural experiment stations, those of Maryland and Vermont, both newly born and still wobbly on their legs, cooperated

in a study of influence of environment on seed stock of the common white potato. Starting with seed from the same source, the stations annually exchanged a part of their seed product, so that the two lots could be grown side by side under both northern and southern conditions. With the first year's crop, differences were slight. By the time the third crop had come to maturity, they were large. For some unknown reason the Maryland grown seed had degenerated—had literally "gone to pieces." Thus one of the earlier of our field experiments established a prejudice in the minds of potato farmers in favor of northern grown seed. That prejudice continues to the present day.

Very shortly was established an array of facts important to agriculture—that seed degeneration in potatoes is a vital matter; that in all southern districts it is very rapid; that it is less, possibly non-existent, in the north. Gradually pathologists came to recognize that in so-called degenerated seed potatoes are conditions which indicate disease. Even to-day they do not know the causal agency involved. Because they have failed in isolating an organism, and because it is transmitted through the tubers, they call it a "virus" disease. Degeneracy in seed stock or the "running out" of varieties is the agricultural problem which was solved in part by the research in question.

The second scene brings us to 1913, when Dr. Orton, of the Bureau of Plant Industry, an expert in plant pathology, suggested certification of potato seed plots as a remedy. This suggestion was based on observations made on German practice in potato culture. In its essentials it requires that seed be grown in a separate plot, instead of being taken from the general field or sorted from the general crop. These plots are to be grown under expert supervision, are to be rogued at intervals and held to certain definite standards. Acceptance of certification was an enormous step forward, yet the results from the use of certified seed were conflicting. Sometimes they were very good; at other times they were extremely discouraging. Sometimes the seed field would seem to be without blemish, roguing would be practically unnecessary, the yield would be all that could be asked. Yet, notwithstanding these favorable conditions, complaints would sometimes follow the use of its product for seed. Typically such complaints showed the development of mosaic or other virus disease in a strain thought to be free from infection. Somewhere was an unknown factor—we were ignorant of when and how these virus diseases were transmitted.

I can not do more than merely sketch the third scene, which is the line of attack developed by the Maine project. That the disease was transmitted through the tubers was already suspected,

although not proven. The research justified the suspicion. The effects of the mosaic disease were measured. The possibility of artificial inoculation was established, as was also its improbability under usual methods of handling the seed crop. It was proven that once a plant becomes diseased there is no chance of recovery for itself or for its vegetatively produced progeny. This fact holds true even though the virulence of the disease manifestation may be significantly influenced by environmental conditions. Utter failure met the attempt to control the disease through seed treatment.

The completion of the final phase of the project was dramatic. In the green aphid, an insect usually considered as being of little economic importance, was found the carrier of the virus. It was shown that a plant from healthy stock can be grown immediately alongside one from diseased stock, even with the leaves in contact, without contamination, if aphids be excluded. Only when the aphid goes from a diseased to a healthy plant is a spread in infection probable. By a most careful series of experiments one factor after another was eliminated until finally the case was proven against the aphid. This knowledge enables us to fill in the missing link in our system of potato seed certification. It shows that in addition to careful inspection and roguing and securing seed stock from sources known to be free from certain diseases, isolation of the seed plot is necessary in order that there may be no near-by diseased stock from which the infection may be carried. Applied in practice, the provision that the seed field must be certain distances from all other fields has made the difference between successful certification and that only partially successful. It has replaced a questioning attitude on the part of the growers with an attitude of increasing confidence.

It now becomes necessary to declare our dividends. The intensive field work was started in 1918 at Aroostook Farm, Presque Isle, Maine, this being a substation of the Maine Agricultural Experiment Station. The first report was published in the *Journal of Agricultural Research* in September, 1919. The Maine Agricultural Experiment Station published its report in 1920. It resulted in a change in the requirements of seed certification. Naturally the full effect of such change can not be measured until farmers generally appreciate the reason for the same and confidence in effective certification is awakened. I shall therefore take the year 1924 as a starting point in measuring our results.

Many states have made fairly accurate measurements of the yielding power of certified over common seed. The Maine station has itself made measurements of the injury done by the presence

of even mild infections of mosaic and kindred diseases. Even when the infection is so slight as not to be apparent to the casual observer, the loss in yield due to its presence may be as high as thirty to fifty bushels per acre. At the Connecticut Agricultural Experiment Station the gain in yield due to the use of certified seed has seldom been less than thirty bushels per acre, has often been double this figure. From these and other results, I estimate that ten barrels or thirty bushels per acre in round numbers may be taken as the normal expectation of the increased crop to be received from replacing the common seed by the certified product.

In 1924, 41 per cent. of the total Maine acreage of white potatoes was planted with certified seed, as against 16 per cent. in the previous year. This was an increase of over 34,000 acres, which on the basis of ten barrels increase to be expected represents an increased crop, a part of which was certainly due to the research in question, of 340,000 barrels. The fact of increased acreage of certified seed is in itself evidence of the increasing confidence in the tool of certification.

In the same year Maine farmers entered for certification 24,357 acres of potatoes; and 14,645 acres passed the final inspection, compared with 6,228 acres passed the year previous. On an average, one acre of Maine potatoes which are sufficiently good to pass certification will plant fifteen acres of commercial crop. The increase in commercial crop which may be expected to follow the increase in certified acreage in Maine in 1924 represents a total potential increased yielding capacity of well over a million barrels of potatoes.

But Maine is a political unit and is far from being a geographical or an economic unit. It is neither possible nor desirable to confine the results of scientific research to a single political unit. The whole northeastern part of the country raises seed potatoes, as indeed do adjacent provinces of New Brunswick and Prince Edward Island. In 1924, out of nearly 42,000 acres entered for certification from New York northeasterly through New England into these two provinces, 28,362 acres were finally passed. This is an increase over the previous year of more than 100 per cent., and a part of this—no one can ever know how large a part—goes back to the research under discussion and must be credited against whatever sum the investigation may have cost.

But the northeastern part of the country is not the only part which is attempting to produce disease free seed potatoes. The aphids are almost universal in their distribution. Severity of outbreak varies from year to year. In every potato-growing region

in the country this research is of significance. 1924 also is but a single year. As far as we now know, the white potato in the future as in the past will be a staple vegetable food. We are unable at this time to put any limit on the number of years over which the country will continue to reap dividends from its modest investment in this investigation.

The real value of work such as this can never be measured in money. It is an insurance of the country's food supply; it represents the means through which the food needs of an increasing population may be met. The best expression of the dividend is in terms of human energy consumed in growing the potato crop. Through controlling the source of seed and using the resources of science to prevent the diseases which cause degeneration, the producing capacity per hour of human labor spent in growing the crop has been increased. It is difficult to make a numerical expression of this increase—possibly it is as high as twenty per cent.; it can not be much lower than fifteen per cent. That this increase is permanent and is worth while will be admitted by all.

But there is a hidden fallacy in my argument. I have not dealt with the numerous other experiments and researches on the same agricultural problem, which failed to attain their objective. In the forty years which have elapsed since degeneracy in seed potatoes was first recognized as such, the problem has been attacked from many different angles. Experiment station literature contains many records of comparative tests on seed potatoes from different sections. Many stations have attempted to solve the problem through hill selection, some even through breeding. For a time it was generally believed that degeneracy was the normal and unavoidable result of continued vegetative propagation. Many of these researches were superficial, in that they attempted to determine facts and gave no attention to the basic causes of such facts. One and all they failed, although the final successful attack was based in part on such failures. A thorough-going discussion of our state-supported research problem must include estimate of the cost of the researches which failed as well as declare dividends on those which have been successful. Even so—if as a result of forty years' work the efficiency of the human beings engaged in growing a staple food product is permanently increased, can any one doubt its worthwhileness?

This brings us to the final stage of the problem—What means do we take, or what means may we take, to present the true facts to our main constituency—to the people who in the last analysis pay the bills?

Through all the usual methods of publicity—through bulletins and circulars, through articles in technical journals, through the public press, by lectures, occasionally over the radio, through personal contact—the facts have been promulgated and in some cases interpreted. The efficiency of any one of these methods, of all of them put together, is, however, limited by the generally accepted idea that the agricultural experiment stations are primarily agencies for the service of a single class. Only when dividends are declared in terms of a material thing, as increase in acres farmed, in product raised or number of people engaged in an activity; in increased price received for a product or in net value of the product, do our statements have the effect which we desire. We can make such statements; I have indicated a few of them. Intentionally, also, I have avoided going into them extensively.

Here we face a peculiar and most difficult problem. The extensive and rapid application of the results of the research just described has indeed resulted in the production of more potatoes, but likewise in a crop of decreased commercial value. Through increasing the productive power of seed potatoes, less land is required to grow our needed potatoes than would otherwise be the case. Through increasing the productive efficiency of labor employed in raising potatoes, fewer persons relative to our consuming population are needed in potato-growing than would otherwise be the case. It is even possible that the Maine Agricultural Experiment Station, working on funds contributed in part at least by the people of the state, has made a discovery which will show other states how their dependence on Maine-grown seed potatoes may be decreased. I am not prepared, therefore, to evaluate this great work in terms other than those indicated, *i.e.*, in terms of real human efficiency in producing a staple commodity. The great gainers are the people of the country. The primary gainers are those few farmers, more expert probably than their neighbors, who first profited by the production of certified seed.

Somewhere I have read the statement that when, years ago, shoe buckles went out of fashion in Europe, the buckle-makers starved. To-day in this country we are facing a somewhat similar situation. Research work carried on in the name of agriculture and for the benefit of agriculture has oftentimes increased potentialities of production without at the same time increasing the possibilities of a market. Both state and nation have gained immensely. So also have our better farmers. Somewhere, however, is a maladjustment in that we are still unable to capitalize a research such as this without causing suffering to certain portions of our population.

THE BIOLOGICAL ENGINEER

By Professor J. ARTHUR HARRIS
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He would be a daring biologist who would attempt to compete with the historian in the evaluation of the contribution of the engineer to human progress. While the historian can not neglect the roads, the aqueducts and the great buildings—erected for the labors of the living and for the repose of the dead—of ancient times, much that is most remarkable in the application of natural forces and resources to man's needs has been accomplished in years so recent that it is fresh in the memory of men now living. We properly study the classics and the arts of ancient peoples for their beauty, but in admiring as well as enjoying the attainments of those older civilizations we should not forget that in our own day the engineer, by applying the results of scientific research, has harnessed and brought into human service those very natural forces before which primitive man trembled in fear and which in a higher stage of culture he deified. Accomplishment has not been limited to the utilization of enormous forces to relieve men and beasts of physical toil. Achievement has been almost beyond itself in the development of instruments of remarkable delicacy for the transmission, detection and utilization of waves of almost infinitesimally small energy value.

It is because of the attainments of the engineer in the application of the results of research in the physical sciences to human welfare that I desire to stress the possibilities of essentially the same methods in the biological fields and to emphasize certain ideas concerning the interrelationship of pure and applied science and of investigation and the practical utilization of the results of research, which have interested me for many years.

In suggesting that the day of the *biological engineer* is not far distant, it is proper to describe, even if we can not precisely define, the engineer, and to indicate his relation to research in pure science.

The engineer is of necessity preeminently practical. The investigator is of necessity to some degree a theorist. Unfortunately, theoretical is too often considered the antithesis of practical. In my own opinion the engineer is practical because his practice is grounded on scientific theory. The success of the engineer in dealing with the concrete is dependent to a considerable degree upon his knowledge of the abstract. We shall not go far astray in saying that the engineer is the agent for the practical application of ab-

stract theory. The investigator who describes the results of his researches in the general terms of scientific theory is practical because in due course of time the generalizations deduced from his observations, experiments and measurements may, and with a high degree of probability will, find useful application in human affairs. The engineer performs an immediate service to our highly organized society by the construction of some instrument for the conservation of natural resources, for the utilization of natural forces or for the increase of human efficiency. The investigator performs an ultimate service by providing the scientific data upon which the engineer depends for the economic usefulness of his work.

As one who has always been occupied with research in pure science, I desire to disclaim any attempt to minimize the work of the constructive engineer by overemphasizing the idea that he merely applies the results of others. In many cases it requires greater ability to use the results of research than merely to contribute to the amassed data of science. Men who have dealt with problems of pure science in the laboratory are broadened when of necessity they undertake application. I do wish to stress the idea that the labors of the two groups of men must be essentially different but supplementary. This necessity for differentiation or specialization of effort has been forced upon us by the growth of science. Because of the activities of an army of workers the recorded observations and generalizations of science are now becoming too extensive to be grasped by any single mind or any well-organized group of minds. As a result we hear much of the necessity for highly organized abstract services and research information service in the field of science.

In a way the growth of science may be likened to that of a coral reef. Only a small fraction of the whole structure is alive. In general, only a small part of the accumulated products of research are of immediate interest to the investigator. I hope I shall not be interpreted as minimizing in any way the work of the engineer when I say that he and the investigator are primarily interested in different strata of the series which constitutes the whole system of human knowledge. The investigator is primarily concerned with the loosely consolidated portions which are just being deposited as the result of current intellectual activities. It may even be said that the investigator is, to an unfortunate extent, influenced in his interests and sympathies, and even in his conclusions, by the scientific fashion of the day. The engineer, on the other hand, is primarily concerned with results which are so consolidated and tested that they can safely be applied in practice. We are beginning to see the baneful influence upon pure science of

the trained investigator having his time and his freedom curtailed by dividing his efforts between pure science and immediately practical projects. We are realizing, too, that many of the men who are assumed to be doing practical biological work in our federal and state institutions are not rendering their best public service because they are dividing their energies. Pure science and applied science would both profit if there could be essentially two groups of men, working in close consultation and often in cooperation, with the fullest mutual confidence and respect, the one group attacking fundamental problems, the other studying the ways and means by which both the long established and the current results of research may be practically utilized. To my mind the great problem of the engineer is to select from the mass of available scientific information the particular portions which may be economically applied to the uses of mankind. To see the needs and to select is a task for men of the ablest and most highly trained minds. Such men should have not merely the confidence of men of affairs but the respect and aid of scientific associates in research in pure science. In return, he should recognize clearly and publicly acknowledge the debt which his success in public service owes to his associates in investigation. The public which expects to profit by the work of the engineer should be given to understand by the engineer himself that such benefits can not be continuously forthcoming without support of the necessary antecedent work in pure science.

Primitive man was an animal living in simple and direct relation to the kindred but potentially lower animals and plants of his environment. In the course of that social evolution which we call the rise of civilization, this simple and direct relationship has been replaced by one of great complexity. Man's effort at self-domestication has resulted in a high degree of differentiation and specialization of social groups. In our modern industrialized society great masses of mankind have been entirely removed from personal contact with the living plant and animal species upon which all must ultimately depend for the essentials for existence. Even those fractions of mankind which do still devote themselves directly to the production of the raw materials for food and clothing pursue some one phase of a specialized, and in some instances highly organized, agriculture.

This development of an intensive and highly specialized agriculture is the inevitable result of two economic factors—the incipient pressure on the immediately available food resources of the world due to the growth of the world's centers of population, and the development of a rapid and world-encircling transportation system by the cooperation of the capitalist and the engineer.

Transportation systems characterized not merely by enormous carrying capacity but by swiftness of delivery and control of temperature during transit have not merely permitted agricultural specialization but, by making it a necessity, have introduced special problems of crop and animal production in every important country. They have had other weighty biological consequences. The congestion of people in cities has introduced many problems of food preservation, storage and deterioration, as well as of sanitation and hygiene. Consumption of agricultural products away from the land on which they were produced has introduced a problem of maintenance of fertility that bids fair to be of great importance. With rapid transportation has come increased danger of the introduction from one region into another of animal and plant parasites of domesticated plants and animals and of man himself—biological factors which may threaten the existence of great industries, of an economic importance to be written in terms of hundreds of millions of dollars. The development of tropical agriculture—the only practicable means for the production of many of the commodities which we to-day regard as essential—has become possible with the growth of shipping, but involves the problem of so modifying conditions of life near the equator as to make them suitable or at least safe for men belonging to races which have evolved under essentially different conditions. Earlier attempts at the construction of the Panama Canal failed, not because of the unsoundness of the work of the French civil engineers but because of the want of biological knowledge adequate for dealing with the great problem of sanitation.

The present century has been characterized by an enormous increase in the number of human beings living under the conditions of physical welfare which we associate with the word civilization. This twofold growth—an increase in numbers of individuals associated with an increase in the number of things which they feel essential to their well-being—has depended in the past upon the development of transportation facilities, upon the replacement of manual by mechanical labor, upon the analytical and synthetic skill of the chemist, upon the evolution of scientific medicine, upon an increase in the area of the world's surface under tillage, upon improvement in methods of crop production, and to some extent upon improvement in the inherent qualities of domestic animals and plants. There are reasons to believe that we are approaching, if we are not already in, an era in which continued growth must depend directly upon a wider application of the methods of science to our great biological problems.

What is essential for success?

First, more fundamental research in pure biological science, with a view to obtaining the precise quantitative information concerning animals and plants which is essential for successful application. Second, the development of a special profession of men of high ability and comprehensive training who shall find the difficulties of application a problem worthy of their best intellectual efforts. Men of this class will devote their attention primarily to a study of practical needs on the one hand and to the possibility of applying the results of scientific research to the meeting of these needs on the other.

I am not unaware of the great accomplishments of those who have specialized in the so-called practical phases of biological work —the pathologists, the agriculturalists and the husbandrymen for all the various breeds of living things upon which we depend for our physical existence. I am not unaware of the fact that the hydraulic engineer has filled an important place in sanitation, nor that the irrigation and drainage engineer has made a large contribution to the growth of our agriculture through reclamation. Neither am I unmindful of the part which the mechanical engineer has played in increasing crop yield per man by the development of agricultural machinery. But these are activities closely akin to conventional fields of engineering.

What we need in addition are men of such breadth of experience that they can make contacts with the practical agriculturalists, animal husbandrymen, transportation executives and public health officials on the one hand and with laboratory investigators on the other, with a view to finding the means of applying the results of the research of the one to the practical needs of the other; men of such vision that they can foresee future needs before they actually arise and prepare to meet them before they become acute.

Up to the present we as a nation have lived primarily by exploitation. The conservation and the development of our biological resources has, in my own opinion, hardly begun. The development of the temperate zone and the conquest of the tropics is only in part a matter of statesmanship, finance, industrial vision and engineering, as we now generally understand the term. It is in large measure a problem for the student of the biological sciences, who must present his results in the quantitative terms which make their practical utilization more readily possible, and for a type of man who is just beginning to develop among us—the biological engineer.

REASON, REVERENCE AND LOVE[1]

By Dr. DAVID STARR JORDAN
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It is a great pleasure and a great honor to me to take part in the consummation of the work of my old friend, Dr. Frank Dyer, in the completion of this great temple, devoted to reason, reverence and love. And the greatest of these is love, as was said long ago, as love is "the greatest thing in the world." But perfect love can exist nowhere far from its two associates, reason and religion.

I have, this morning, the modest hope of achieving, not their final agreement, for that was assured in the work of creation, but a much less mighty result, that of their reconciliation in the minds of some of those to whom I speak.

Under the names of science and religion reason and reverence have been through the ages in recurrent conflict. I believe that this conflict has been the result of ignorance, a clash of new experiences with old tradition, the association with the name of religion of matters largely imaginary, or else belonging wholly to the province of science. Such discords are destined to pass away as our understanding of the universe and its ways becomes broader. Religion finds its center in the feeling of reverence and in the call of duty. There is nothing in the nature of knowledge that should conflict with this. There is nothing in the nature of religion which should inhibit the widening of intelligence or its extension to all within our reach in the universe in which we form a part. "The heavens declare the glory of God" far more in our own day than in the period when man's knowledge was limited to what was actually within the range of his eyes. When the spirit of religion is transformed into a system of belief involving statements of scientific or of historic fact, it becomes encrusted with superstition. To abate superstition is one of the chief functions of science.

The scope of science is the entire range of knowledge of the objective world. In its expansion it has the single method of tested and verified human experience, aided by such tools of precision as may be devised, the human reason being itself the most important. While imagination is one of the most useful of these tools, it can not of itself extend knowledge, but at the most indicate lines of exploration. It is a basal proposition of science that *we know noth-*

[1] Address at the dedication of the Civic Forum of the Wilshire Boulevard Congregational Church, Los Angeles, June 7, 1924.

ing until we find it out, and that no authority, actual or conceivable, can give answers to objective problems in advance of observation or experiment.

The scope of religion deals with human relations to the unseen powers around us, "the infinite conscious intelligence" that pervades the universe and our relations towards one another. The beginnings of religion like those of science are crude and modest, rising from fear of the unknown and invisible through fear, awe and reverence. Science or classified knowledge serves three fundamental needs of humanity. First, it enables man to help himself to the service of the forces of nature by adapting them to his purposes and adapting his purposes to them. This is "applied science" or engineering, using that word in its broadest sense to include sanitation of all grades. Second, science controls the conduct of life by tracing and registering the results of lines of action. This is ethical science, and the result of experience gives us the only test of right and wrong. Third, and not less in importance, science broadens the human mind and releases it from the cramping effects of reliance on tradition and on authority. Science opens the way to freedom, the only freedom there is, the release and development of one's own personality. "At the last, nothing is sacred save the integrity of your own mind." The scope of religion concerns our relations one towards another and to the unseen and unmeasured powers which surround us in the universe in which, in Huxley's words, "nothing endures save the flow of energy and the rational order which pervades it." Its beginnings, like those of science, are crude and narrow, rising from simple fear of the unknown and intangible through awe, reverence, worship and duty, culminating in helpfulness and purity, to visit the widow and fatherless in their afflictions, to keep one's self unspotted from the world.

Coordinate with the spirit of religion is the spirit of love, beginning far down in the scale of life, with conjugation of independent cells, but rising to be potentially "the highest development of altruism," the love of man and woman, the love of mother and child.

Evolution is "orderly change." Its way is the way of all things we know. Nothing is static in human life or in the universe about us, of which we can know nothing until we find it out, not think it out, but prove through observation or experiment its actual objective reality. Furthermore, whatever exists, an object or an event, has a cause behind it. All change is orderly, and we know of no source of order except an ordering or pervading intelligence. Hence evolution is but another name (and that none too well chosen) for nature.

And in nature the most elaborate, most perfect, most advanced result of orderly change is humanity. And in humanity the crown-

ing glory is in the mind. In the perfection of the mind, three features stand first, closely kin to one another, equally sacred, equally inborn and perennial, equally necessary, all three alike subject to suppression or perversion. These are reason, religion and love. Of these three, reason and its product knowledge stands as the regulator of emotion, and thus the backbone of conduct.

Science deals with realities, that is, with objective facts as impressed through the several senses on the nervous system of man. It is human experience tested and set in order. The conclusions of science are thus to be distinguished from memories (or past realities), fancies, superstitions, illusions or isolated facts not yet set in order. Fundamental to science is the conception that order exists throughout nature, and that there is no source of objective truth other than the human senses. Knowledge progresses as these are tested, verified and expanded through use of instruments of precision. The scope of science includes therefore all objective truth and it questions the validity of any other.

In the reality of the objective world, the integrity of science, the sanity of man are alike bound up. The distinction between objective and subjective, between reality of perception and illusion of nerve disorder, between fact and dream, between presence and memory, is fundamental in human psychology—is essential in human conduct.

The word religion is used in several different senses, these bearing a certain relation one to another, but by no means identical in fact or in spirit. From the standpoint of scientific analysis, religion is the instinct of fear, awe, reverence, worship, faith, duty, arising from the recognition of the gigantic forces which surround humanity, and of our desire to act in accordance with their supposed purposes in our pursuit of happiness.

In a historic sense, a religion is definable as the form in which the spirit of reverence has become embodied in human institutions. It is a system of belief, as well as worship, and as such, ceremonials, symbolisms, poetry, organizations and creeds have grown up around it either as aids or parasites or both. Thus an important branch of science is the study of comparative religions. The distinction between these two uses of the word is indicated in this epigram: "Religions die: religion, never."

Religions are historic and traditional. Religion, like hope, "springs eternal in the human breast," and is as likely to be found in dissent from a historic religion as in conformity to it. It is as natural and fundamental as the feeling of love to which it is closely akin. Both "spring eternal in the human breast," and both, as I have said, are alike subject to suppressions and perversions.

The name religion is also popularly used for dogmas, ceremonies, rites, symbolism, organizations, which have as their real or nominal purpose the aid to religious feeling, the control of religious activities or their concentration on the advancement of the individuals concerned or of the world at large. The word is also loosely used for any condition in any way allied with worship or propitiation of unseen powers. In so far as religion is compacted or crystallized into a system or a belief, it becomes at once encrusted with extraneous matters, poetry, hopes or superstitions.

In the strict or scientific sense religion is personal or individual. No one can take up the religion of another. In the historic sense one may join another's communion, enter another's cult or accept another's creed. Individual religion admits of no compromise. Organized religions are products of compromise, each communicant having a different mental picture of the central purpose if he rises to any conception at all. From the standpoint of science, the question as to whether any religion is true has no meaning. Religion itself is not concerned with statements of fact, either of science or of history. The actual problem is whether impulses, actions or opinions, called religion, work out for human betterment. "Pure religion and undefiled" is not concerned with theological subtleties, and a test of religion is the one offered by Jesus to Peter: "Feed my lambs."

It has been questioned whether the vague mythology of primitive man should be regarded as religion. But it is from crude beginnings that all higher powers or impulses arise. In our understanding human reason is developed from tropism and reflex action, simple reactions which in the lower animals or in human infancy precede the power of choice. In like manner we may include under the general term of religion all the various functions and impulses in the childhood of the individual or the race that lead upward to its higher manifestations. These constitute an obvious series: the highest stage involving an effort to conform to ways of righteousness established by a power higher than ourselves. At the heart of religion is the hope that by our conduct we may place ourselves in line with the will or the ways of the power we worship. In the earlier stages of humanity the invisible deities may be many in number, with varying powers and caprices, but the tendency of intellectual advance is toward the conception of a unified intelligence in a unified universe. This "rational order" which pervades all nature we can not describe nor circumscribe, for we can not speak of it in any term of human experience, nor can we grasp the character of that unconditioned source of matter and force to which with endlessly varied conceptions we give the name of God.

His "purposes," to use a human word, we know only by what He permits. In His sight (using again our limited phraseology) that is right which endures. That which seems to exist in the nature of things if proclaiming itself as powerful men have worshiped as divine, the more so if its origin and relations have been dimly understood. Force felt in darkness inspires awe. A god visibly built of a block of wood has never appealed to serious men. To the weak it is a tangible symbol of what they can not otherwise hold in mind. But it is the hidden force invisible, not the wood or stone before which men bow in worship.

So far as humanity is concerned religion and science are of the same age and must lead finally to the same end. We have been, each of us, thrust suddenly into a gigantic universe. Knowing nothing of the past, present or future, except as we can trace it by the dim light of our own observations and experiments and the recorded experiences of others, we find ourselves surrounded by creatures more or less like us and just as bewildered, and again encompassed by natural objects we can see and feel and by mighty powers we can neither see nor understand. And we find that unseen forces though not tangible are just as potent as the others and just as capable of tremendous disturbance of our daily actions. To stand in awe before the unseen is the beginning of religion, to attempt to find out how it behaves is the beginning of science. To be just and kindly towards our fellowmen and to be devoted towards our own family is the function of love, a sentiment as old as animal life, the traces of altruism appearing even in animals of a single cell and outrunning conflict through the world of animal life. "This world," says Arthur Thomson, "is not the abode of the strong alone: it is also the home of the loving."

Every robust human life is a life of faith, not faith in what other men have said or thought or dreamed of life, or death, or fate, not faith that some one afar off or long ago held a key to the riddle of existence, which is not ours to fashion or to hold. Not faith in mystic symbolisms which only a priest may interpret. Let us say, rather, faith that there is in the universe some force or spirit which transcends humanity, but of which the life of man is part, not the whole, something which is intensely real and which it is well for men to recognize, for to follow its ways brings effort and action, peace and helpfulness, the sole basis of happiness.

WILL THE FRENCH RACE BECOME EXTINCT?

By HAROLD G. VILLARD
NEW YORK, N. Y.

ALTHOUGH victorious in the World War and possessing the strongest and best equipped of all existing armies, the French people yet feel insecure. Their almost stationary population and Germany's actual and potential superiority in man power makes them apprehensive as to the future. If the French race should dwindle in number hereafter, as now seems likely, France's position as one of the world's great powers will become endangered.

At the outbreak of the French Revolution in 1789 France had 26,000,000 inhabitants, a greater population than was possessed by any other European country. This preeminence in point of numbers she lost to Russia after the Napoleonic wars, in which three million Frenchmen are estimated to have lost their lives. Despite this heavy toll of French manhood, the French people gained quite rapidly in number during the first quarter century after the downfall of Napoleon. About 1840, however, a change occurred. The French annual birth-rate, which had been over 31 per 1,000 inhabitants from 1801 to 1831, began to decline, while the death-rate decreased only slightly. The result was a marked falling off in the yearly percentage of growth of the French population.

When the Franco-Prussian War broke out France and the states which afterwards were included in the German Empire had about the same number of inhabitants. This equilibrium was upset by the cession of Alsace-Lorraine to Germany. Nevertheless, even after the loss of these since regained provinces, France had 36,190,000 people left and was still the third most populous state in Europe. But this rank she was unable to retain for long, because of the relatively insignificant additions to her population. Before the close of the last century the inhabitants of Austro-Hungary and the British people both outnumbered the French.

Between 1871 and the outbreak of hostilities in 1914 the population of Germany jumped from 41,000,000 to 67,800,000 or almost two thirds, and that of Great Britain from 31,556,000 to 46,081,000 or nearly fifty per cent. During the same period the French population rose from 36,200,000 to 39,800,000, a gain of only one tenth. Had that rate of growth continued unchecked these three countries

could have counted on doubling their population: Germany in 65 years, Great Britain in 87 years and France in 430 years.

This poor showing of the French was due to the small excess of births over deaths during the period in question. Indeed, in the seven years 1890–92, 1895, 1900 and 1907 more persons died in France than there were living children born, while the average gain in population between 1901 and 1913 was only 58,000 per annum. This slight growth was not sufficient to arrest the depopulation of the French rural districts, the number of whose inhabitants shrank from 24,868,000 in 1871 to 22,093,000 in 1911 or a decrease of one ninth. While it has been calculated that the average family in this country, which has a considerably higher birth-rate and a much lower mortality rate than France, must have 2.6 children to maintain the population of the United States at its present level, the census of 1911 revealed that the average French family had but two children as compared with 4.2 offspring in 1801, the exact figures being 11,696,663 families and 23,059,032 children.

Statistics prove that as many people marry in France as elsewhere and that the proportion of childless marriages is not abnormal. In the case of the United States it has been computed that one marriage in six is either sterile or leads to no live issue. In France 157 out of every 1,000 families were without living children in 1911. The lack of progeny in France was not due, therefore, to an inability to procreate children but rather to a systematic limitation of their number. After having brought one or two children into the world the majority of French mothers stopped having any more. Of the 11,696,663 households enumerated at the time of the 1911 census 7,432,859 or almost two thirds were found to have two children or less. While selfishness and a desire to evade the responsibility of bringing up children was a contributing factor, the main reason for the small size of French families has been excessive parental love.

Unlike this country, where sons and daughters are expected as a rule to make their own way in the world as soon as they have attained their majority, French parents allow their children no initiative and feel obligated to provide for their future. They also want them to rise in the social scale and, with this object in view, seek to establish their sons in some profession or government post and to endow their daughters with a handsome marriage portion. The fewer children there are the greater the likelihood of their aims being attained.

Moreover, France is a country of thrifty peasant proprietors, who cultivate small strips of land and who are passionately attached to the soil. In 1921, 5,219,464 independent landowners were enu-

merated in France, of whom over 2,000,000 owned less than two acres. The French Revolution, however, did away with the law of primogeniture. According to section 745 of the French civil code, a man's real property descends to his children in equal shares, irrespective of their sex. Hence peasants and small landowners who either want their holdings to descend intact or whose properties can not be advantageously further subdivided have every incentive to limit themselves to one child.

This equality of inheritance provision has been held by French writers to have been one of the principal reasons why the population of their country tended to become stationary before the World War. From that sanguinary conflict France emerged victorious but with the flower of her manhood gone. Within her former borders and without Alsace-Lorraine, 38,468,813 persons of French descent resided at the time of the 1911 census. In 1921 only 36,084,266 French citizens were counted in the same area, a decrease within the decade of 2,384,547 souls or one sixteenth of the purely French population existent in 1911. This loss was partially made good by the reannexation of Alsace-Lorraine, which contained 1,709,749 inhabitants in 1921 as compared with 1,874,014 inhabitants in 1910, when the last German census of these provinces was held. With Alsace-Lorraine included the total population of present-day France was only 39,209,518 in 1921 as compared with 41,476,272 in 1911. The population in 1921 consisted of 37,659,059 French and 1,550,459 foreigners.

Of the 2,000,000 or more French that were lost during the World War, 1,350,000 were killed in battle, while the decrease in the French birth-rate during the war period accounts for the remainder. In each year from 1914 to and including 1919, more people died than were born in France, the excess of deaths ranging from 53,327 in 1914 to 389,375 in 1918. When the war ended patriotic Frenchmen were urged to marry and to help make good this decimation of the race. If France is to live, her people must be more prolific, exhorted the press, while Clemenceau declared in 1919 that the war would have been fought in vain if the French women did not bear more children.

At the same time legislation was passed to facilitate the raising of large families. Money grants, preferment in appointment to official positions, reduced taxes and lower railroad fares were some of the rewards offered fathers with numerous offspring. Bonuses for married employees gauged according to the number of children were even introduced. But all these appeals and inducements have been without effect. The last census showed that French bachelors

numbered 3,000,000, while the French birth-rate is virtually the same as ten years ago. In 1922 and 1923 it was 19.4, last year 19.2 and in 1913, 19.1 per 1,000 of population.

Another disquieting fact for those who had hoped to see the French multiply faster after hostilities ended is that, although the population is about the same, thanks to the recovery of Alsace-Lorraine, the number of children born in France is now less than before the war as a glance at the following table will make clear:

Year	Births in France
1913	790,355
1920	834,411
1921	813,396
1922	759,846
1923	761,861
1924	752,101

The abnormally high totals reported for 1920 and 1921 were due to the unusual number of weddings that took place after the Armistice, which in many cases represented unions that had to be postponed on account of the war. The normal number of babies in France is about three quarters of a million per annum. But this yearly crop of new lives is insufficient to maintain France's population intact. If that is to be kept at its present level 900,000 infants a year must be born, as a prominent French deputy has shown in a recently issued pamphlet, provided, of course, that the mortality rate undergoes no change.

Although the French are not reproducing themselves, they have not as yet begun to die out. In the last three years, 1922–24, the excess of births over deaths in France was 237,666 or at the rate of 80,000 per annum. While no statistics are available on this subject, some experts are of the opinion that this excess of births is in a large measure due to the presence of several million foreign laborers on French soil whose home birth-rate is higher than that of the French native stock. Should conditions remain the same as now, however, the scale will before long be tipped the other way. For during the war years the French birth-rate fell off more than 50 per cent., which means a corresponding drop between 1935–40 in the number of young men and women able to marry. During these years or shortly thereafter, the French marriage rate will be halved, with the inevitable consequence of a like proportionate decrease in the birth-rate. Thus the slight annual gain that is now taking place in the French population will be more than wiped out a decade hence. Then the twilight of the French race will truly set in.

While the French people are barely holding their own in numbers for the time being, other countries are adding very largely to their population. Between the census of 1919 and the one held in June, 1925, the population of Germany rose from 59,178,185 to 62,474,872. Of this gain of 3,296,687 or 5.57 per cent., 3,252,200 was due to the excess of births over deaths. The estimated population of England and Wales was 36,800,000 in 1919 and 38,746,000 in 1924, an increase of nearly two millions in five years. Italy's population is mounting at the rate of 450,000 per annum, so that the Italians will soon outnumber the French if they do not do so already. Of all the civilized states France makes the poorest showing as regards excess of births over deaths, as is borne out by the following figures appearing in a recent issue of the *Journal Officiel* and which give the excess of births over deaths per 1,000 inhabitants during 1923 in the countries hereinafter named:

Country	Excess per 1,000
Holland	16.1
Italy	12.6
Norway	11.5
Denmark	11.0
Finland	9.9
Scotland	9.9
Spain	9.2
England and Wales	8.1
Switzerland	7.6
Belgium	7.4
Sweden	7.4
Germany	7.0
Austria	7.0
Ireland	6.9
France	2.4

Asked why his nation should for years past have stood at the foot of lists of this description the average Frenchman will cite as a reason the so-called "crisis in natality" raging in his native land and the disinclination of French women to bear more children. But, while to a certain extent true before the outbreak of the World War, this excuse no longer holds good. In the matter of bringing future citizens into the world French mothers are nowadays not far behind those of other countries. This is shown in the following table, likewise taken from the *Journal Officiel.* It gives the number of births per 1,000 of population during 1923 in fifteen of the European countries:

Country	Births per 1,000
Spain	30.4
Italy	29.1
Holland	26.0
Finland	23.7
Norway	23.0
Scotland	22.8
Denmark	22.3
Austria	22.3
Germany	20.9
Ireland	20.6
Belgium	20.4
England and Wales	19.7
Switzerland	19.4
France	19.4
Sweden	18.8

The above quoted rate for France is undoubtedly too high, as it has been calculated on the assumption that the French population in 1923 was the same as in 1921, whereas it was swelled during 1922 and 1923 by the net immigration over all departures of 323,000 alien workmen, many of whom brought with them their wives and children. But, even if allowance be made for this error, the French birth-rate shows up well. The truth is that in all civilized nations the birth-rate has been tending downwards for many years past, so that to-day Germany, England and France are in this respect not far apart.

This continuous fall in the birth-rate has been offset in most countries by a corresponding decline in the mortality rate, thus enabling the population to grow steadily though not in quite the same ratio as before. This statement does not hold good of France, however, which, with the exception of Spain, has the highest death-rate of any Western European nation, as the following table, first published in the *Journal Officiel,* makes manifest:

Country	Deaths per 1,000 in 1923
Spain	21.2
France	17.0
Italy	16.5
Austria	15.3
Germany	13.9
Finland	13.8
Ireland	13.7
Belgium	13.0
Scotland	12.9
Switzerland	11.8
England and Wales	11.6
Norway	11.5
Sweden	11.4
Denmark	11.3
Holland	9.9

In the United States, where living conditions are exceptionally favorable and the death-rate has fallen faster than the birth-rate, about twice as many people are born each year as die. In 1923 the corresponding ratio in England and Wales was three deaths to five births, in Germany two deaths to three births and in France seven deaths to eight births. Until 1900 Germany had a higher death-rate than France, but since then conditions have been reversed. In 1923 and 1924 more children were born in France than in England and Wales, although the populations of the two countries are within a million of each other. Despite the initial advantage of 34,545 more births the natural increase in population, that is, the excess of births over deaths, was during the last two years only 167,087 in France as against 570,533 in England and Wales. Because the latter country has been able to hold its death-rate down to two thirds of the French death-rate its population is increasing three and a half times as fast as that of France.

France's real cause for worry, therefore, is not her low birth-rate but rather her very high death-rate, which must be reduced if she would keep pace with other countries in the matter of population. As her birth-rate is low her death-rate ought to be also low, for the reason that the mortality rate in the first quinquennium of life is much higher as a rule than at any subsequent one until the age of sixty is approached. Thus in England and Wales the mortality rate for all ages in excess of five years was 11.04 per 1,000 persons living at those ages in 1913, while for ages under five years the mortality rate was 35.7 per 1,000. Any advantage that might be derived from a lower infant mortality is more than offset in the case of France, however, by the fact that in that country there are fewer children and young people and a larger proportion of aged persons than elsewhere. In 1911, for example, the average age of the French population was thirty years and that of the people in England and Wales twenty-five and three fourths years. The difference may not appear very great, but in comparing French with English or other mortality statistics allowance must be made for this variance in age composition. Although France possesses an older population the average duration of life there is shorter by some three years than in either England or the United States.

But infant mortality figures based on the number of children under one year of age dying in a given calendar year as contrasted with the total number born during the same time are directly comparable. As regards such figures France does not make as good a showing as England or this country. For instance, in 1923 761,-861 children were born in France and 758,386 in England and Wales. Yet, although the number of the newly born was virtually

the same, 73,283 infants that had not attained the age of twelve months died in France during that year as compared with 52,362 in England and Wales. As France possesses on the whole a remarkably healthy climate it should not prove an impossible task to lower the infant mortality rate materially through the introduction of improved child welfare measures.

The death-rate from tuberculosis in France is much higher too than in Spain, Italy or Germany and is twice that of the United States and England. Of the persons aged between twenty and forty years in 1913, 6.93 per 1,000 died in France as contrasted with 4.43 in England and Wales. Nearly half of the French deaths were due to tuberculosis. The death-rate from this dread disease in France could be quickly cut down by abandoning the practice of herding young men in unsanitary barracks and by demolishing the germ-infested habitations in the old portions of French cities.

The higher general death-rate in France is also explained by the unsanitary conditions under which the great mass of the population live and their lack of personal cleanliness. In his book, "My Second Country," Robert Dell justly points out that in Paris (which is the most advanced in sanitation of all French cities) a large proportion of the houses are unattached to the main sewerage systems and are drained into cesspools. The French peasants live under filthy conditions, with animals in their houses, while there is no proper inspection of factories and workshops, which are terribly unsanitary. If this state of affairs could be remedied there is no reason why the age composition of the French population should not in the course of a comparatively short while approximate that of other peoples, for France's high mortality rate is not due to climatic, racial or other unpreventable causes.

However, to provide the French people with sanitary dwellings, a purified water supply, adequate milk inspection and to teach them modern methods of hygiene will require a very considerable expenditure. But France has no money available for such useful outlays, as disbursements for her huge military establishment and the interest on her crushing debt absorb most of her budget receipts.

The French would thus seem to have it in their power to decide whether they will increase in time in the same proportion as other European peoples or become ethnically extinct. They must improve living conditions at home or their ranks will continue to be thinned by disease as now and they will slowly but surely shrink in number. If they resolve to remain the world's foremost military power and to carry the burden of a great colonial empire with all the attendant sacrifices they cripple themselves from introducing

the housing and sanitary reforms essential to their survival as a great race. They are therefore confronted with a fateful decision.

Whatever their choice it is improbable that France will become depopulated hereafter. Only half as densely peopled as Germany or Italy, she has had to call in thousands of alien laborers to till her soil and to help develop her industries. At the close of 1923 the number of foreigners in France had reached 2,800,000. Of these 700,000 were Italians, 550,000 Spaniards, 500,000 Belgians, 400,000 Russians and 200,000 Poles. They constituted one fourteenth of the total population. But the French do not easily assimilate the nationals of Latin and other countries, few of whom elect to become French. In 1924 only slightly more than 3,000 foreigners became naturalized French citizens. The real peril confronting France is not depopulation but denationalization. Before many decades these alien workers and their descendants may outnumber those of true French extraction.

A ROMANTIC IN BENGAL AND IN NEW YORK[1]

By Dr. ELSIE CLEWS PARSONS

I AM a man of *magha,* for I was born under Magha, the tenth of the twenty-seven stars who were daughters of King Daksha. This is a dangerous star to start a journey on—on arrival you will meet with death, not in body, but in your plan or prospect; but Magha is a most auspicious star to be born under, meaning wealth and fame. Of a distinguished and prosperous man people will say, "He must be a man of *magha.*" In three ways I have become distinguished. Some people speak of me as the man who is a prodigy with numbers, others say I am a fine actor, others say, "There is the wonderful man who was initiated with his dead wife." I have had a very romantic life, but in wealth I have not yet succeeded, and my journey to America has not been successful.

My family lives in Dacca District, Bengal, in a village in the plains, the largest in the district, from ten to twenty thousand in population. We are Kasyathas,[2] our family (*padhati*) name is Bose. Ghosh, Bose, Guha and Mitra, these are the highest among the Kasyathas. These *kulin* Kasyathas came into Bengal in chariot, on horseback, on elephant-back, not as servants on foot. Datta is the fifth *padhati,* it is half *kulin.* Their ancestor was lacking in one of the nine virtues possessed of the others, he was lacking in reverence for the Brahmins. . . . There are in all one hundred and two divisions of the Kasyathas. My wife was Bal.[3] My great-uncle also married into her family. It was a glory to them, to marry with our family, as we are superior to them. When our

[1] With the narrator of this autobiographical account I was recently engaged in a systematic study of Bengal kinship terms and social organization. There was much of a biographic nature as well as cultural which was recorded during our acquaintance, and this part of the record is here given, in the mouth of the informant, an extraordinarily intelligent man, a conservative, and, from our point of view at least, an uncritical philosopher. To psychologist and ethnologist alike, such a combination of mental faculty and of cultural naïveté is of arresting interest.

[2] A division of the second highest caste, Kshattriya. The three highest castes, Brahmin, Kshattriya, Vaisya, are all Aryan, in Hindu opinion, the fourth caste, Sudra, are aborigines. Men promoted from the cow become Brahmin (good men, priests), from the lion, Kshattriya (heroic men, warriors and scriveners); from the monkey, Vaisya (lustful men, merchants).—"We differ from Darwin on this point," remarked Mr. Bose.

[3] A *padhati* of the Kasyathas. Padhati(s) are exogamous. Caste and sub-caste are endogamous.

men dine with them the first time, our men are paid for it, several rupees.

The descendants of my great-uncle and my grandfather live together. We live in joint family, the descendants [in the male line] of these two brothers. In Hindu society sons always live with their father; after he dies, the brothers and their families go on living together; the separation usually comes between brothers' sons. But in our case the brothers' sons have staid together. My father is the son of the older brother, but he is himself younger than the son of the younger brother, so he is not the Master of the family. My "uncle" is Master. He is an old man of seventy-five.

Usually a man as old as that has given up the responsibility for the household to a younger man, his younger brother or his son; but not so my "uncle." He has ruled us very strictly. He made all the disbursements for the household; he is a miser, too, and very unpopular in our village, indeed so unpopular that for the last five years he has not lived there, but away, in Munshigong. Formerly he was a school inspector. Now he is rich, and out of the service. Rich people don't need to take government service.

My "uncle" has given us our names. Usually several persons in the family suggest names for a child, in connection with the rice-giving ceremony, and one name is chosen; but in our family my "uncle" gives the names. He chose the name of my son and my name, Somesh Chandra, from Soma, Moon, isha, lord, Chandra, Moon. My son's name is Pinaki, from the musical instrument held by Siva. Pinaki was nicknamed Lord Canning—most people have nicknames—and he is so bright they call him Cunning.

The names of Siva or Vishnu appear in many names. It is auspicious for a man on dying to call on the name of God. So we give names of the gods to our children, that when we call them to us when we are dying we may be also calling on God.

My father's name is Umesh Chandra, Lord of Uma or Durga, *i.e.*, Siva, and Moon. My mother's? I can not say it, I will write it. We may not speak our mother's name. (He writes: Bilash Kamini, Luxury Lady.) This is an ugly name. My wife had a beautiful name—Sarajubala, Saraju is a sacred river, *bala* means girl. It is very romantic that when I was a little boy I fell in love with that name. I read it, and fell in love with it. I said that I would not marry any girl without that name, and my relations would say, "We will get a wife for you with that name." When I heard of a marriage I would ask the name of the girl, and when they told me, I would say, "I don't care for her name. She has not the right name."

The first wife of the cousin-brother we call *bara dada,* big brother, he is the eldest in our generation, had a pretty name, Pankajini, Mud born [? Water lily]. She was a poetess. Her son is now a student in the University of Chicago. She died when she was seventeen. Within six months *bara dada* married again. It is permissible for a man to remarry after the *sraddhu* ceremony [death feast and close of funerary taboos], that was held by us thirty days after death, but why did *bara dada* want to marry again at all? A Hindu woman who has lost her husband never marries again. Why should a man who has lost his wife?[4] I first asked that question when I was twelve, when *bara dada* married again. They said, "If your wife dies when you are married, you will marry again." I said I would never marry again, and I stopped speaking to *bara dada.*

At eight I was going to a Bengali school. Before that, in my fifth year, the family summoned our family Brahmin to perform for me the rite of "beginning education." Into my hand he put a pen and guided my hand into making letters. There are thirty-five consonants and fourteen vowels in Bengali, and I did not want to learn them. Finally, one day when I was about six, my father said that until I had learned those letters I could not come to a meal. In half an hour I knew them all. They said then that I would be a memory giant.

At the age of eight, my son will be taking sacred thread,[5] but I did not take sacred thread until I was twenty, when all the men in our family took it together, young and old. In Bengal until the last few years only the Brahmins took sacred thread, the mark of Aryanism. The Brahmins said that there were but two castes in Bengal, Brahmins and all the others, all, Sudras. Bengal Brahmins

[4] In "Lectures on Vedanta Philosophy," to the naïve quality of which there are supplementary illustrations in this story of one who is a Vedantist, Vivekânanda writes: "Take up one idea. Make that one idea your life. . . . Let the brain, the body, muscles, nerves, every part of your body be full of that idea, and just leave every other idea alone. . . . this is the way great spiritual giants are produced." (P. 70) S. C. B. is practicing this instruction, consciously, I think. Monogamy absolute is his object of concentration. Almost all subjects of conversation are brought around by him to this theme, of it he talks on all occasions, the most inopportune, and to all persons, the most indifferent. "All nations will have to believe in marriage like this," he says, but his talk is not of the nature of propaganda as much as pursuit of "concentration."

[5] It is of native grown white cotton, in three strands, each of three threads. One or even two strands may be loaned, in an emergency, but one strand must be retained. Sacred thread is never left off, except by accident when, deprived of sacred thread, one would not speak. The thread is touched while saying the mantras (prayers) belonging to it, to the goddess Gayatri, who dispels sins.

are very selfish. They are the least spiritual, too, in all India. They eat eggs, meat, fish and onions. . . . Now the Kasyathas determined to take sacred thread. They found that without it their fellow castemen outside of Bengal did not care to dine with them. Also it was argued that unless they had sacred thread they might lose the right to have their women, like Brahmin women, give evidence, in law cases, at home, through an intermediary; their women might have to go publicly to court. So Brahmins were paid large sums to give us sacred thread. Without the Brahmins we could not take sacred thread. They have to perform the ceremony. Besides nobody would revolt against Brahmins, because everybody believes in *khama* or reincarnation. You are a Sudra in this life for sins in your past life. If you live properly as a Sudra, you may be a Brahmin in your next life.

Well, at nine I went to an English school. Without an English education one can not get employment in India, and in our district one has to be learned to make a living. One day when I was ten or eleven the school inspector had asked our class to multiply three numbers by three numbers. I was the only boy out of the forty who could do it. He gave me more figures, four numbers by four numbers, and I did that. I told my family and they would try me on multiplying. When we had guests they would bet me the sweetmeats I was very fond of that I could not multiply their figures. So by the time I was twelve I could multiply fourteen figures by fourteen. Then I began to lose interest in developing this gift. Who are the great men of India, I was asking myself. They are the saints. I will become a saint. Of what value is my gift to a saint? I neglected my gift, rather I practiced austerities, for example, I would sleep without pillow or cover.

In H(igh) E(nglish) school I had double promotion three times, and graduated in seven years and went to the college. After two years I took the examination, and got a position in Calcutta as assistant accountant.

I was fond of acting. Our village boys organize themselves into actor companies, men taking the women's parts,[6] and give plays in vacation and are invited to perform at weddings. That was how I came to see my wife. I went in a dramatic company to the wedding of her brother. I saw her twice and then I learned that she bore my chosen name. She was beautiful, but her religious attainments I valued even more. . . . Since my wife's death I have not acted, nor will I ever act again, or even go into the theater. Before she

[6] There are no actresses in the village. They live in the cities, in special quarters. They are so hated and despised that if a man touches merely the shadow of one he will take a bath, even a low caste man, an aboriginal.

died I was going to take the part of a very beautiful man. I had a tooth missing and she advised me to have a tooth put in, the better to look the part. It was done,[7] but she died before the performance. So I said I would never act again. My friends say that by dying my wife spoiled their amusement.

My son, who is only seven, can act the three principal parts: the pathetic, the heroic and the comic, using the right tones and gestures—the female tone for the pathetic, a loud tone and sweeping gesture for the heroic, the gesture of twirling mustaches for the comic. We give him sweetmeats for his performance.

My wife, too, was a good entertainer, but of course she performed only at home, for her sisters-in-law. She would not sing or play before her mother-in-law. Even to talk with the superiors [seniors] in the family a daughter-in-law must have the consent of her father-in-law or her husband.

I saw my wife on the first night of her brother's marriage ceremonies. On the second night men and women are in different rooms. The second night we call Black night. The night of the wedding bride and groom sleep together, the second night they must not see each other, otherwise the marriage will not be fortunate. They say that Dasaratha, king of Oudh, saw his third queen, Sumitra, on the second night, and afterwards they separated. King Dasaratha was the father of an incarnation of Krishna.

When I went home, through friends, I told my parents that I had found my wife. I did not speak directly to them about it, for nobody speaks of getting married to their parents. A girl would never think of speaking of it. If she did, she knows people would call her shameless. "A girl of twelve, she talks about marriage with her parents! Shameless girl!" A boy would *never* speak about it to his father, he might speak about it to his mother, if he likes; a mother is more affectionate and familiar than a father.

I told my friends, "I am married already." My friends advised my parents to consent. "If you want your son to lead a worldly [household] life get him that girl," they said, "for never will he marry anybody else." I was their eldest son, I was twenty-one, it was time for me to marry, so they consented. Our wedding day was May 6. According to the almanac[8] of that year that was the most auspicious day of the year, and that month [lunar month]

[7] For my western tour I had two teeth put in the front of my mouth. When I return I will take them out. God did not give me these teeth; why should I use them?

[8] An almanac is published two or three months before April 14, New Year. As the almanac gives the auspicious days for ceremonies and for almost everything you have to begin, it is one of the most valuable things a Hindu can own.

is always auspicious. My wife was thirteen.[9] That is about the time nowadays that we like girls to marry. Not to have a daughter married before her menses is a disgrace and "second marriage," which is the ceremony after first menstruation, is always performed. A girl's first menstruation in her father-in-law's house is always assumed to be her first. My wife's second marriage was performed two months and a quarter after we were married, the sixth night after the appearance of the menses. Prognostication is made according to the date of this event. Of my wife it was predicted that she would be *patibiata,* a girl to whom her husband is god-like, an object of worship.

A girl's education is begun by her parents; it is carried on by her husband. He should be the first man she cares for. If she does not marry until she is sixteen or seventeen she may have been in love with some other man. Formerly girls were married at eight; that is still better for their education, and conservative Hindus would like to go back to that practice. But in those days nothing was paid for bridegrooms. The bridegroom himself made a present to the girl's family, and that was a good practice, for it was a sign that he would be able to support his wife properly. To-day the bride's father has to pay, sometimes so much, particularly for a highly educated bridegroom, that they have to wait until they can afford it. Sometimes even girls of twenty are not yet married. Money is paid to the bridegroom's father because he wants to be recompensed for the expense he has been put to in sending his son to an English school—an English education is very expensive.

Formerly young people used to arrange their own marriages—I was doing nothing out of our own tradition. To-day we have professional matchmakers, although family connections are also asked to make matches. In several cases I have been asked to do so. I know what the requirements are. My sister's sister-in-law asked me to arrange a marriage between her daughter and our father's sister's daughter's son. He was highly educated, he could speak English very well, he was very beautiful, they were rich, they were of superior *padhati,* but his father was a dead drunkard and so was his brother, perhaps he would himself become a dead drunkard. They did not live in joint family, they were selfish people. All

[9] Actually twelve years and seven months, as I was twenty years and seven months. We were born in the same month. In our case the astrologers were not called in to determine whether the signs of the zodiac we were born under were mutually auspicious. If the horoscope is inauspicious, showing, for example, that although sons would be born they would die, the marriage will not be made. Parents think of the future, the young people, if it were left to them, would not. They would say love is love. . . . In our case the matter was left to God.

this I told my sister's sister-in-law. She wanted me to make another choice. I proposed my wife's brother, Satishmohan. "Compared with the other boy," I said, "he is just as beautiful, just as white, he is rich, too, but he is inferior in *padhati*, and he is not highly educated. On the other hand, his people live in joint family, with much religious instruction." The girl was married to Satishmohan.

Also, I have chosen girls in three or four marriages. I can tell when a girl will keep her figure. Mostly after a girl has had even one child her figure changes, it is no longer beautiful. After my two sons were born my wife was just as beautiful as before. Figure, contour of the face and color are standards of beauty. Often in the same family one daughter will be white and the other black. In the case of the less beautiful, the darker one, more will have to be paid for a husband, or a husband of inferior *padhati* will have to be selected. Parents pay a great deal of attention to color. They know that it is inherited, particularly if both the parents are dark. If their daughter-in-law is dark, she may have a daughter who is dark and then they will be put to large expense in marrying off their granddaughter. Marry her they must, for no family with an unmarried girl is respectable. Suppose there are two girls in the family, the elder, dark, the younger, white, still the elder must be married first. Always the elder sister or elder brother must be married before the junior can marry. Although in the case of boys an older brother who does not want to marry can give his consent to his younger brother marrying. Among my connections this has happened twice. One man who is now over forty has not married, he is the richest man in his village, but it was his whim not to marry, and so he gave consent to his younger brother to marry. In another case the boy was feeble-minded. My father was his guardian and he would not consent to his marriage. The boy wanted to get married, and he kept sending matchmakers to see my father; but my father said that he would not make any girl so unhappy; she would see that in our family where all the men were intelligent and well educated and good earners only her husband was not, that would make her morose. So this boy had to give his consent to his younger brother's marriage. But at it my mother first married the elder cousin-brother to a cockroach by rubbing vermillion on the head of the cockroach. Whenever we see a cockroach now, we boys always laugh and say, "There goes our sister-in-law." It is a great joke with us.

We joke a lot. Life in joint family is very cheerful. Western visitors who go only to the cities do not appreciate how cheerful and happy village life is, nor how poor—since the English occupation. The Bengal staple is rice, and formerly one maund (80 lbs.)

of rice cost two anas (four cents), now the cost may be as high as a rupee($3.00). Formerly people did not have to go to work outside their household. Each household was self-sustaining. Now they must get employment outside. And even so, they can afford, in many cases, only one meal a day. Many, many village people are always half-starved. Four years ago twenty million perished, mostly from starvation.

The rich men are almost all Vaisyas, the third caste, merchants, traders. The millionaires are bad men, mere tittle hunters. They subscribe large sums to what the British Government wants, for a tittle, they give nothing to humanitarian work. A Brahmin widow with a son seven years old went to one of these millionaires, a man I know, and asked him to let her have a few rupees a month to educate her son. He refused. "What credit is there in it for me?" he said, "Nobody would know about it." Another millionaire told me I should go to England and America to show Western people what a Hindu brain could do, to exhibit my mathematical gift, and he promised to finance my trip. So I talked about going, for two years. But he didn't pay, yet I had to go; for, wherever I went, my relations and friends would ask me, "Well, when are you going?" To save my prestige I had to go. But I had no money, my rich "uncle" was too stingy to give me any, and my salary as assistant accountant in Calcutta was small, only thirty dollars a month. From bidding contractors accountants can make as much as seven thousand dollars in one day. That I would never do, for I am honest. So I borrowed the money to travel, $3,000, from three men, expecting to make it back by exhibiting my gift.

I would lose my gift, my friends had told me, when I married. "You are very foolish to marry," they jested, "you have a great gift, you will lose it." I did not agree with them; that was not my idea of marriage. "Two halves make one," I said. "Husband is half, wife, half. It is the same soul divided in two." So, for the glory of my wife, I began again to develop my gift. From multiplying fourteen figures by fourteen which is my *natural* power, the power I had in a previous life, I succeeded in multiplying sixty figures by sixty figures,[10] and I did square roots up to the eleventh

[10] This I had reached to when my wife died. Since then I have not tried for higher figures. And when I return to India I will not calculate any more at all. It does not contribute to a saintly life. [It is an astonishing display in ordinary life. In less than five minutes Mr. Bose found for us the fifth root of 1,418,514,742,349; the quotient of 73 divided by 182 to several decimal places; and the product of 67,325,098 multiplied by 592,637, *giving the answers together*, at the same time. At the start, when I hushed the group of college boys who were setting the examples, Mr. Bose said quiet was not necessary, so one played the piano, another fired off a pistol, the others talked.]

root. While I was concentrating on figures, in the posture of meditation, my wife also practiced concentration, in a meditative posture. She would sit in the same room, she could keep her posture, which was a difficult one, for twelve hours. She sat cross-legged with arms behind back, right hand holding right foot, and left hand holding left foot. For four hours she could gaze up to her forehead, on the spot between the eyebrows. That keeps you from thinking of anything else. I can do that only for two hours. My wife in meditating would concentrate on my face, as now when I meditate I concentrate on the face of my spiritual guide (*guru*).

Before our second son was born my wife was ill. "What will you do if I die?" she asked me. "I will kill myself," I said. "That would be very wrong," she said, "strong men should not commit suicide. There is our son for you to make a man." She made me touch her and promise that I would live to take care of our children. Then my wife died, four years ago. She was twenty-two. She died in full consciousness, uttering the names of deities. . . . At the burning ground after my little son had lit the first fire, putting the brand on her mouth, two men started to hold me from jumping. I said, "Let me go. I will not jump. I am under promise to her. Otherwise you could not hold me, I would be too strong."

At the very moment of my wife's death I gave up eating meat, fish, eggs and onions. Rice I still ate, for the satisfaction of my family, to please my mother, five times a week. Widows may eat rice even more frequently; my widowed relations tell me that I have surpassed them even.

Now I desired to set out and visit the saints, to find a saint who would initiate me together with my wife on my left side—that is the position of a wife with us. So I asked my parents' consent. They refused, they feared I was going to renounce the world and that they would never see my face again. "You may go," they said, "but without our consent." Now we believe that whatever we do without the consent of our parents will fail. So I did not go; I knew that I would not find the saint I sought.

But I said to my parents, "You had best consent, or worse will happen." In a few months my second son died. As they were taking his body out to the burning ground I said to my parents, "You see what I feared has come true. Now lest further misfortune happen, will you consent?" They were afraid my other son would die, so they at last gave their consent to my going. . . . . The household was assembled. My mother gave me her blessing by placing rice and grass on my head; my sisters (my inferiors because my juniors) placed it on my foot; I saluted all in turn, touching

their foot, or having my own foot touched; from the leaf-covered water jar at the door I plucked a sacred leaf, and, uttering a *mantra* [prayer-formula], I passed out of the door.

I travelled over India—fifteen thousand miles by rail—and I saw thousands of saints. I found many with wonderful powers, saints who because they were always truthful knew the truth about everything and everything they said had to come true, had to happen; saints who were never envious, wanting nothing from any creature, and so no creature could take from them or harm them; saints who wanted nothing in the world and so everything in the world was known to them and they realized God; and saints who were very, very old, one was four hundred years old; but not one of these saints would undertake to bring my wife back and initiate us together. I felt frustrated. Finally I came to Hardwar, and there found Giri, who is the greatest saint under the Himalayas, and president of the association of saints at Haridar (Hardwar). He could talk to me in Bengali.[11] "Why do you wish to have your wife with you?" he said. I explained to him that my wife was advanced in the practice of meditation before she died, and that wherever she was she was still advancing, that I could not desert her, that all other women were as mothers to me. He was pleased with what I said and he agreed to initiate us together, on condition that what converse I had with her I was never to reveal. We were initiated together, in a cave. All I can say is that for a half hour I had great enjoyment, I was as happy as it is possible to be. . . .

Since then I have practiced meditation daily from two in the morning to six. I begin by uttering *mantras*, invoking Shiva. Then, without words, I concentrate on the face of my *guru*, in my mind, I mean of course, although I have his photo with me, together with my wife's. I have told my landlady when she sees no light in my room not to disturb me. I sleep only three hours or three hours and a half, some nights not at all, and yet in the morning I am not tired, I am perfectly fresh. During the past week I have slept only two hours. In sleeping posture your *kunda kundalini* (coiled), that is the life that is *coiled* in you, is in your abdomen. It is your duty to awaken this *kunda kundalini*, so that this snake will pass from abdomen to the soul space in the forehead, through rising in the canal in your back which we call *shushumna*. Ordinarily this canal is closed; in meditation it opens, and sometimes

[11] Other saints I could not talk with properly, not speaking Hindi, which is the general language, although it is not known as well as English, particularly in Bengal. There are five hundred different dialects in India, we are told. Even in Bengal we don't understand the talk all over. If people from Chittagong speak quickly they can not be understood at Dacca or Calcutta.

in sleep, when the snake peeps into it and we can then dream wonderful things. But ordinarily in sleep we are spending at a high rate, at thirty. Normally we are spending life at the rate of twelve (we live at *baramatra, bara,* 12, *matra?* times). The rate goes up to sixteen when we cry or raise our voice as orator or actor; a voracious eater spends at twenty; one running, at twenty-four; one lusting, at thirty-six. By the breathing exercise of *pranayama* (inhaling, holding, exhaling, at the ratio 1:4:2) the rate of spending is reduced, we control and prolong life. My *guru* has not given me this *pranayama,* and until he gives it I would not attempt it, it is very dangerous and causes insanity in those unfit for it. But my *guru* has given me the best posture, one that disciples of even twenty years may not have got.

I drink a quart of milk a day, that is all my diet. And now I weigh one hundred and twelve. The saints never eat meat, fish, eggs or onions, least of all onions. All these foods interfere with meditation, they are too exciting.[12] Widows, too, do not eat these things. At home I eat from the widow kitchen. The widow or fishless kitchen is kept so separate that you may not go into it from the general or fish kitchen without taking a bath in the tank, an "under water bath." This bath a woman has to take on rising before she can cook. It has to be taken, too, on return from a funeral or after touching by accident an Untouchable. Some people take an "under water bath" two or three times a day. . . . We can not bathe properly in the West. Bathing in this country we don't call bathing. Submersion is the only complete bath. . . . In this country we prefer a shower to a tub, there are germs in a tub.[13] Yes, everybody can bathe in the tank, even Untouchables, at separate hours. The water is dug down to, it does not run.

At home I drank water, except on Monday, which is the day of the week my wife died. On that day[14] at home and here, too, I take less milk, too, than usual, and sleep less. Since I set sail from Southampton, on September 21, [nine months ago] I have not touched a drop of water. I have not been thirsty here. In London I was thirsty, for on the steamer from India I lived entirely

[12] Besides, in the meat of both chicken and cow there are many germs of tuberculosis. Sheep and goat, physicians tell us, it is safe to eat.

[13] An interesting illustration of completely identifying cleanliness with godliness, and of how if the trait of exorcism is omitted, cleanliness as such may go, and I think does go, by the board.—E. C. P.

[14] Nor will I do anything on that day to bring me credit, like displaying my calculating gift. [I happened to ask Mr. Bose on a Monday to show his gift to some guests, and he declined, postponing it to the next evening. On another occasion I had proposed that we work together the day following—April 26, but that day was the fourth anniversary of his initiation and he had planned not to leave his room.]

on flour I brought with me. On the steamer from Southampton to Canada I ate one apple a day. The forty-five days I was detained by the emigration office I could not get good milk. It was thin and dirty. I weighed only one hundred pounds. I thought I was going to die. I wrote that to my people in India. They got very much excited. It was in the papers in Bengal, the way I was being treated in Canada. The emigration office wanted a bond from me. So finally the richest Bengali[15] in New York who owns two houses there, took my $500 and went on my bond in Canada. . . . If I took up political work in India my experience in jail in Canada would count. A sister government, Canada, keeps in jail for forty-five days a man from her sister government in India! . . . Five years ago I would protest about anything that was against my principles. Now I keep silent, I will not quarrel.

I told the officials in Quebec I would not take a job in America, so I can't work here, it would commit me to a lie. I am hoping that Mrs. ——— will give me the money to pay off my loan. I worry over it, although my brothers write, "Why do you worry? We are four brothers, we can pay it off." If Mrs. ——— gave me enough money, I could also leave my son and my parents provided for and devote myself to spiritual life. She might give me money to do humanitarian work for Untouchables. . . .

Some of the Untouchable castes have been agitating for the privilege of being shaved by the barbers. Ten years ago I made speeches for them. My voice is very powerful. I can control an audience of fifty thousand. . . . I have been told in New York that if you are taken for a Negro a barber may refuse to shave you. I have been into several barber shops to see, but I have not been refused yet. In London I saw that Hobbes, the great cricketer, had to eat in a room with the professionals, and gentlemen would not eat with professionals. Is that not caste?

In London I was very much surprised by the good manners. On the street people would show you the way, even going with you. I met no Englishmen who were not gentlemen. My people will not believe this when I tell them, for in India we meet no Englishmen who are gentlemen. There may be English gentlemen in India, but we don't meet them.

I met a gentleman in London called Brown. One time he said to me, "I trust you will soon become a Christian."—"Why?" I asked him. "Because the Son of God came to earth." But among us God himself came to earth. Foolish Mr. Brown!

[15] There are in New York about twenty-five high caste Bengalese.

I want to be back in India in October for Durgajuba. That is the greatest religious celebration of all India. Everybody goes home then. On that day even a Brahmin will embrace a Sudra. My younger brother will first salute me, then I will embrace him. All through the month when people write letters they say, "Accept my Durgajuba greetings."

On my return, the women in the neighborhood will *ululu*,[16] as they do in all ceremonies and for a distinguished visitor and for one back from an important journey. It is a very good thing to hear, it makes us feel solemn and religious. I may have to perform the rite of atonement [exorcism] which is done for any infraction of ceremonial or caste usage. My hair will be cut, and mantras said and money paid to Brahmins. What was not sacred has gone, now again you are sacred, is the meaning of this rite. When it is due, unless it is performed, a person is treated as an outcast, none will speak to him, nor allow him into the house. Anciently, it is said, Hindus could cross the Black Water without atonement, but I may have to perform the rite on my return from America.

[16] An inarticulate sound from the throat is uttered while the tongue moves rapidly from side to side of the mouth, the lips being protruded.

DEMOCRATIC LEADERSHIP

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I

THE spectacular universalization of the democratic form of government has not by any means silenced criticism of the democratic way of life. The basis of criticism has shifted, however, as democracy has passed from victory to victory in its world-wide conquest. Gone, for the most part, are those sturdy characters who once stood out openly against the popular advance. There is a frankness about Plato and his kind that one who lives amid the current strategy of indirection must admire. Plato charged outright and in the open that democracy was bad because in its madness it sought to equalize those whom nature had differentially endowed. He would have none of it, unless under duress. Aristotle, though more tolerant, was still frank in his criticism. And even on the very threshold of our century, Sir James Stephen spoke as a fearless and free man in declaring that "no room is left for any rational enthusiasm for the order of ideas hinted at by the phrase, 'Liberty, Equality, and Fraternity'; for . . . there are a vast number of matters in respect of which men ought not to be free; they are fundamentally unequal, and they are not brothers at all, or only under qualifications which make the assertion of their fraternity unimportant."[1] Writing a dozen years later, Sir Henry Maine,[2] whom the discerning student is likely to feel little more sympathetic than was Stephen, spoke much more softly regarding democracy. Its greatest merits, one gathers from him, are its internal inhibitions against its own success. Verily, the worldly prosperity of democracy has softened the tongues of critics, even though the hearts of many of them remain heavy and fearful.

Since Maine, it is only now and then that a lonely Faguet cries out in the wilderness his whole mind regarding the popular idol.[3] Even the old and disillusioned have learned from the racy wisdom of the young that, though you dislike the hand that feeds you, it is better to manicure than to bite it. There is pathos in Lord Bryce's conscious effort "to repress the pessimism of experience," as well

[1] "Liberty, Equality, Fraternity," p. 318 (1873).
[2] "Popular Government" (1886).
[3] "The Cult of Incompetence" (1914).

as a moral in the reason he assigns for it—"for," as he says, "it is not really helpful by way of warning to the younger generation, whatever relief its expression may give to the reminiscent mind."[4] We have come upon days in which it seems that the dearest enemies of democracy have sublimated their fear of popular violence and their love of private property and have articulated their sublimation as a deep solicitude for the health of democracy itself.

The most common form this solicitude takes at present is a lament over the poverty of democratic leadership. Democracy, in the estimation of these all too eager doctors, finds itself, like so many delicate mothers, unable to nurture its children to maturity. It must, therefore, in order to achieve its own ends, call in the skilful help of those who, drawing their wisdom from an unrevealed source, pine to spend and be spent for the welfare of this deserving patient. Even Faguet reveals to those who pursue his heart beneath his bellicose title—"The Cult of Incompetence"—a deep longing to save democracy by furnishing it gratis an aristocratic leadership. President Nicholas Murray Butler, of Columbia University, many years ago offered to America the same friendly service as that of Faguet to France. Knowing that "liberty is far more precious than equality, and the two are mutually destructive,"[5] he counsels us to "put behind us the fundamental fallacy that equality is demanded by justice"[6] and to see that "the United States is in sore need to-day of an aristocracy of intellect and service."[7] But the highest achievement in the art of indirection must be credited to those who in a vein of delightful irony call themselves humanists. With some qualifications, Irving Babbitt may be taken to represent their attitude.[8] Professing solicitude for democracy and setting out to cure its ills by providing a superior leadership, he praises democracy with faint damns until our whole social order stands subservient to an aristocracy the real nature of which is disguised by its being called a class of "workers." But it turns out that instead of being either manual or intellectual workers, they are "ethical" toilers, and the only work they do is to live upon the fat of the land and furnish society a noble example by merely being themselves, illustrious and idle. Manual toilers must humbly remember, however, that they also work who only stand and pose. This salvation of democracy through the proper leadership is what its author pleasantly calls substituting "the doctrine

[4] "Modern Democracies," I: ix.

[5] "True and False Democracy," p. 57.

[6] *Ibid.*, p. 15.

[7] *Ibid.*, 14.

[8] "Democracy and Leadership" (1924).

of the right man for the doctrine of the rights of man!" Verily such wily Antonies come to bury, not to praise, democracy. Were such men alone in questioning the potency of democracy to create adequate leadership, we should know how to deal with them. We should regard them either as strategists or as naïve men self-deceived into believing that the voice of their private interests is but the echo of humanity's need; and their plans, one and all, we should treat as destructive propaganda.

But the situation can not be so summarily dealt with, because there are among those who bewail this democratic weakness men who are at heart friends of democracy and exemplifiers of the democratic way of life. So we are deterred from making short ugly shift of our enemies by the surprising presence of our friends in their front line. When William James, who was a natural democrat, emphasizes leadership as being the crucial test for democracy, we are deterred from dismissing it as being entirely a false issue. And when Lord Bryce, who was intellectually at least a friend of democracy, not only accepts leadership as being the democratic touchstone,[9] but then concludes that democracy "has not enlisted in the service of the state a sufficient number of the most honest and capable citizens"[10]—we are given further pause. But when Professor W. E. Dodd, who is both a natural and an intellectual democrat, bewails the quality of leadership in our democracy,[11] we are forced to retreat from the fray and think the matter over.

II

And the faith of at least one democrat is not shaken by taking this sober second thought. Faith that is not blind corrects itself and renews itself by viewing alternatives. Now whatever may be the defects of democracy, the only possible alternative is of such a character as to renew faith in democracy, however poor it may be; for the contrast is at bottom between forging one's own ends—roughhew them how one may—and lending oneself to further the ends of another. This is really no alternative, for individuality arises only with the assumption of the responsibility of directing one's own life. And what will a man give in exchange for his soul? But even the gloomiest pessimist does not put the alternative quite so sharply. It is not a question of leadership *vs.* anarchy, but of better *vs.* worse leadership. It may be that those who cry up the need of leadership are demanding a type of leader-

9 "Modern Democracies," II: 551.

10 *Ibid.*, 562.

11 *The University of Chicago Record*, X: 109–114.

ship that democracy not only can not produce but a type also that it does not want. Meeting this difficulty, let us make a distinction between traditional leadership and democratic leadership.

The contrast here intended is between the leadership of prestige based upon authority and the leadership of knowledge based upon facts. The one is a matter of status and may even be hereditary, the other a matter of insight and achievement. The contrast may be better brought out by taking each type where it flowers most luxuriantly—in absolute monarchy and in science.

III

The absolute monarch was once upon a time a leader in every department of life: giver of laws, setter of manners, establisher of religion. As a trivial current example of what once prevailed on a grand scale, consider the influence of the Prince of Wales upon current masculine style. It is said that at least one American clothing manufacturer almost faced bankruptcy recently by the sudden change of style attendant upon the royal visitor's taste. Generalize this case from manners to morals and from morals to politics, and you get the ideal leader of tradition: a man whose every word and deed and whim set a precedent, because he was he. Those doughty men of old who went always at the head of every procession—they were the grace and the flower of the old order. Often allying themselves with deity, they sometimes essayed in moments of supreme kingliness to order nature herself into subjection; and in the imagination of articulate admirers both the winds and the seas obeyed them. This philosophy of authoritative leadership idealized the all-or-none principle: one, an all-leader, the rest of mankind, altogether followers.

I do not mean, of course, to imply that in actual fact leadership has ever for any length of time rested on sheer arbitrary authority: even absolutism bears within itself fated seeds of a more humane order. There is in man that perverse loyalty to ethical form that makes the sheerest tyrant uneasy unless his authority can be displayed as resting upon right rather than upon whim or force. Slavery in America, for example, was first recognized as an unnecessary evil blamable upon the mother country and awaiting only an occasion to be remedied. But becoming economically profitable during the interim, it evolved into a necessary evil. Given time, any evil that is necessary ceases to appear evil at all. And so through the metamorphosis of a century slavery emerged in moral habiliment, christened by Calhoun as a "positive good" and justified not only by the common welfare but also, as Professor Bledsoe

argued, by the good of the slave himself. The *malum in se* of one century became the *bonum in se* of the next: the right by might became the right in reason. Aristocratic leadership has never for long masqueraded as arbitrary. Indeed it has been at pains always to perfect techniques for preventing this. One simple way has been to assume that most men do not know what is good for them. If religious sanction can be so used as to content common men with the belief that "it is not in man that walketh to direct his steps," the rest of the way is easy for aristocrats. One of Plato's subtlest devices for guaranteeing inequality was thus the founding of leadership upon insight so esoteric that only a very few could ever discover the common good. Plato's justification for his philosopher-kings is the common justification the world over for the leadership of authority: superior wisdom has been vouchsafed to the few. Follow them and be happy, desert them and be damned. The easy way with dissenters is to declare, with Jonathan Edwards, that discontent with the established order is the surest mark of those foreordained to damnation. To disclaim against social injustice is in some governmental democracies still a jailable offense.

Spite of all devices, men have of course always questioned the bases of such leadership—indirectly when it was not safe to do so directly. When Socrates was told by the young Euthryphro that the gods constituted the celestial Supreme Court on all questions of morals, he queried searchingly as to whether an action is pious because pleasing to the gods or pleasing to the gods because pious. And the Middle Ages—when to challenge authority directly was not prudent—sought to resolve the question as to whether divine leadership was of the prestige or of the knowledge type; for of course the quarrel between the Franciscans and the Dominicans as to the primacy of intellect or of will had precisely this meaning. Given a geographical habitation and an earthly name, the controversy was over the relative merits of absolutism and democracy. Thus vaguely but surely did coming events cast their shadows before.

IV

The arrival of democracy, accompanied and reinforced by science, ought to have changed this conception of leadership; for it is perfectly obvious that leadership in science is of an altogether different mold. That the old notion of leadership has disappeared so slowly is, however, not without explanation. One indeed ceases to wonder at its persistence in democratic societies when he remembers on what absolutistic foundations modern democracy was built. Be it remembered that both in America and in France we built

upon natural rights and self-evident truths—that is, upon a foundation that could not be questioned without branding the questioner either a fool or a dishonest man. This was well enough as protection against our enemies who had made the logic, but it left no way for friendly engineers to safeguard the foundation against the inevitable wear and tear of the inexorable years. Foundations laid outside the domain of reason are not subject to repair and reconstruction by reason. It is significant that the two modern countries that built in dead earnest upon natural rights initiated democracy only by revolution.[12] Utilitarian England was able to come to the same pass by discussion rather than by bloodshed. Fighting is indeed the only way to end an argument the major premise of which is that your opponent is a fool. Renouncing the efficacy of human discussion for the certainty of natural rights and winning our initial success only by the ordeal of battle, we have continued the precedent by believing in a "manifest destiny" apart from the guarantees of human intelligence. Building beyond our resources, we have relied on occult and transcendental agencies to see our project through. Our susceptibility to, and even partiality for, a leadership that rested upon prestige drawn from esoteric sources have thus been but a piece with the other dependence we have placed on vague authoritarianism.

The foregoing philosophic reason for the longevity among us of an outgrown conception of leadership is reinforced by a commonsense reason based upon persistence of a deep illusion of childhood. Adults mediate the physical environment to childhood, and impress the child, his confidence once gained, as being far wiser than they are. This dependence upon the funded wisdom of another in moments of personal trouble is so easy a way of life that in most of us it long outlives childhood. One does not have to be a Freudian to understand how the child pursues this eidolon from parent to teacher, from teacher to hero, from hero to heaven. Our emotional nature hankers after the departing dream of omniscience long after our intellectual nature is content to give it up as another dear but dead illusion. So long as men cultivating this illusion, as in orthodox Christianity, demand as compensation for human loneliness a "friend behind phenomena" and as compensation for personal fallibility an omnipotent, omniscient leader, so long they are not prepared wholeheartedly to accept such sheer experimentalism as democracy has had to content itself with as a foundation. The acceptance of the democratic hazard is hindered

[12] For an elementary, but very stimulating, discussion of this point, see Columbia Associates, "Introduction to Reflective Thinking," Ch. IX.

also by that human inertia that makes it comfortable for one to lie back on his oars in the comforting belief that another wiser than he is guiding the craft aright. When such comforting phantoms are slain in one form, they return in another guise—like the hero of a once popular ballad who, when his legs were shot away, fought still upon the stumps. Eternal vigilance against these spurious hopes is the price democracy must ever pay for its liberty; but that such vigilance taxes human nature to the limit is seen in the lingering way democracies say good-bye to the ideal of absolutistic leadership.

V

It is, I think, the persistence of this outworn conception of leadership that accounts in the main for our disconcerting discovery of some of our friends in the front line of the advancing enemy. Both Lord Bryce and Professor Dodd, for example, show contamination with this older ideal by their emphasis upon *political* leadership as being the type by which democracy is to be judged. Lord Bryce goes so far as to say that democracy should denote no more than a form of government.[13] Professor Dodd, though clearly having a feeling for the contrast between democracy as a form of government and as an ethical way of life,[14] nevertheless turns all too easily to judge democracy by the kind of political leaders it has produced. Taking such men as Jefferson, Lincoln and Wilson as the flowers of our democracy, he bemoans the fact that "only once in half a century or so does there appear a master leader."[15]

This common predilection of men like Bryce and Dodd for regarding political leadership as of typical, if not of superior, importance in a democracy suggests strongly the presence in their minds of a lingering loyalty to a concept once universal but now—thanks to science—no longer in unquestioned repute outside of politics. The politician's infamy, to adapt Pope's famous couplet, does not grow out of the fact

> That he was the first by whom the plan was tried,
> But that he is the last to lay prestige aside.

Religious leaders whom one could have longest forgiven for allegiance to the old—so indigenous is the idea of authority to their profession—are going before the politicians into the kingdom of democracy, for speaking no longer as ones with authority, they are more and more content to join the scribes and sociologists in humbly

[13] "Modern Democracies," II: Ch. 8.

[14] *International Journal of Ethics*, 28: 465–84.

[15] *The University of Chicago Record*, X: 112.

following the trail of the facts. It is only the political leaders who still on principle point to themselves rather than to the facts, who depend upon mystic phrases uttered in pious tones, for attracting and retaining followers. Here and there indeed may be found a Borah who suspects that knowledge is not wholly alien to the political enterprise. Dr. Gosnell,[16] through his recent analysis of the leadership in New York of Boss Platt, has shown us, however, how deep-seated and persistent is the old type of leadership in current political life. Prestige is indispensable to its success, and the knowledge upon which it relies is more likely to be of men and of strategy than of ethics and economics. In the words of William Bennett Munro's new book,[17] it is "personality" that counts in politics.

VI

Science has discredited this type of leadership by the simple process of revealing that nature is too tough to be subdued by phraseology and of showing that it is impossible for any one man to know as much about the natural conditions of human welfare as these spectacular leaders of the past should have known to fulfil their promise. This science has done by throwing light upon both the nature and the goal of knowledge. To Plato—and his influence on history has been profound—the technique of knowing was nonsensuous if not indeed semi-mystic, the process led outside daily life into an unchanging world of pure Forms; and the objects of knowledge, once it reached its goal, were primarily for contemplation rather than for use. Science, however, has shown us that knowledge is not something got at by incantation, nor revealed the better to prestige and pomp. It has indeed abolished the royal road to wisdom through the backdoor of the mystic mind and has insisted that we seek knowledge by detailed observation through the frontdoor of our human senses. Along with this changed nature, science has given to knowledge a new goal.

Passing from the Socratic conception that knowledge is virtue and coming to the Baconian view that knowledge is power, man-come-of-age knows that it is not to palaver but to insight that we must look for control of the factors that condition our human living. So long as men had neither knowledge of nature nor the technique whereby to acquire it, so long had they to be guided, if at all, by fabulous reports of esoteric leaders who claimed, if not to have seen deity face to face, then at least to have looked in on his hinderparts. Such an experience has constituted more than one Moses

16 "Boss Platt, and His New York Machine" (1923).
17 "Personality in Politics" (1924).

an authoritative leader for life. If one wishes to see how antiquated such a philosophy of leadership really is, let him but inquire what it is that constitutes Michelson a leader to-day in physics or Burbank a popular leader in horticulture. The older leader was strong in proportion to the ignorance of his followers; scientific leadership is strong in proportion to the intelligence of the followers. The strong tendency for all of us to think in terms of the one rather than of the other is explained by historic reasons, but is it justified by a comparison of the benefits mankind reaps from the two types of leaders?

Faguet has happily conceived the transition from the old to the new type—a change which he laments—as being the process of relegating the old men to the shelf. "An interesting treatise," says he, "might be written on the rise and fall of old men. Civilization has not been kind to them. In primitive times, as among savage races today, old men were kings. Gerontocracy, that is, government by the aged, is the most ancient form of government. . . . All this, however, is very ancient history. That which undermined the authority of old men was the book. Books contain all science, equity, jurisprudence and history better, it must be confessed, than the memories of old men. One fine day the young men said: 'The old men were our books; now that we have books we have no further need for old men.' "[18]

As a matter of fact the relegation has gone further still. The books that supplanted the old men have been in turn supplanted by the laboratory; and the old men who refuse to abdicate in its favor have been reduced from respected impotence to ridiculed relics. Hear Galileo's letter to Kepler, while the process was going on, regarding professors of authority, who in his day stood out against the new idea of leadership.

> Oh, my dear Kepler, how I wish that we could have one hearty laugh together! Here at Padua is the principal professor of philosophy, whom I have repeatedly and urgently requested to look at the moon and planets through my glass, which he pertinaciously refused to do. Why are you not here? What shouts of laughter we should have at this glorious folly! And to hear the professor of philosophy at Pisa laboring before the Grand Duke with logical arguments, as if with magical incantations, to charm the new planets out of the sky.[19]

And while, of course, it need not mean hostility between the young men and the old, a great change has gone on to make possible this new attitude toward life and leadership.

[18] "The Cult of Incompetence," pp. 146–148.

[19] Lodge, "Pioneers of Science." Quoted here from Burtt, "The Metaphysical Basis of Modern Physical Science," pp. 66–67.

The gist of this modern attitude may be put in a few words: There is no rightful authority save the authoritative situation. The wise man alone can be our leader, and the wise man is he who can best size up the situation, can best get at all the facts. But even he must not interpose himself between us and raw experience. His function is to point, not to order. We follow him only as he follows the facts. We follow him not because we attribute to him occult insight, but because in the distribution of labor it saves time for our specialty if we take his word for the facts in his own field of special experience.

Science, like industrialism, rests squarely upon this principle of the distribution of labor. The moment any man speaks in his own person rather than in the name of facts by which men must live, that moment he slips back to an ancient order and so far forth undermines the integrity of science. The necessity for leadership in our modern life grows out of the impossibility of any man's being omniscient. But this lack that necessitates leadership indicates the kind of leadership needed. It is of the piecemeal type. In order to know enough to lead *here,* I must choose to be relatively ignorant *there.* That means that the choice that makes me a leader *here* requires me to be a follower *there.* But I must demand of him whom I follow, even as he demands of me, that he shall not put either his prestige or his interests between me and the facts. This clearly means that in a civilized society, every man must be a follower in many fields. The only alternative to being a follower in many fields is being a follower in all fields. For he who to-day thinks to speak with authority on things-in-general remains a fool at home, and even his servants lead him.

But the peculiar virtue of a democratic society is that, recognizing that every man must be a follower in most fields, it gives each man an opportunity to be a leader also somewhere. It does this by emphasizing liberty, out of which alone can grow responsibility. It does it by emphasizing equality, which, among other things, means the right of even the humblest to live by the facts rather than by the pretensions of the proud. It does it by emphasizing such education as will fit every man to get at the facts that lure him most. And knowing that no man will live happily without truth, it develops a philosophy that so re-defines truth as to make it a mundane value of the common man rather than a transcendental goal accessible only to an intellectual or moral aristocracy.

And since democracy as a way of life does, and as a form of government ought to, aim at the greatest common good through the

development of each individual to his highest, it must be judged not by its ability to produce a few "master leaders," in deference to whom human nature abdicates its highest prerogatives, but by its ability to make every citizen a creative leader in some enterprise, however small, and at the same time a contented but critical follower of superior insight in other fields, however extended. This means of course that the crucial test of democracy is the health of science under its patronage; for if leadership grows out of a knowledge of the facts rather than out of egoistic pretensions, then it is to the laboratories and experiment stations that we must look to find those who are actually mankind's most indispensable leaders. Friends of democracy will judge France by its ability to produce not Poincaré, but Pasteur; America by its ability to produce not Washington, but Franklin. This means in the large that democracy succeeds in proportion as it discovers a form of education calculated to get at the bases of physical and social living and then makes this education accessible to all its citizens. So judged, democracy makes, heaven knows, a poor enough showing; but a showing not to be ashamed of. So conceived, it is a program yet to be adequately tried but one that faith must uphold with the desperation born of knowing that there is no humane alternative. So long, certainly, as democracy is judged by its ability to produce the kind of leadership that would subvert it, we are in a poor way to make our criticism of democracy constructive.

VII

In thus putting a supreme emphasis upon knowledge as the basis for democratic leadership, it may be objected that we are overlooking an indispensable characteristic of leadership—impartiality. This is an objection that will bear inspection, for certainly this has been the golden objective of older philosophies of leadership. Why this virtue has been so emphasized is easy to see. An all-powerful leader backed up with adequate prestige who is biased for some, and against others, would prove in the long run insufferable. How insufferable indeed such leadership has proved may be read in the unending tale of political revolutions and social rebellions that make up so much of human history. Given a ruler with irresponsible power, clearly impartiality in its use would constitute a subject's best protection. It is the least ethical demand that could be made of a ruler, and at the same time a logical expectation of one whose claim to lead completely outruns his knowledge.

Professor Krabbe has indicated in a recent book, "The Modern Idea of the State," the various expedients that aristocratic times proposed for the attainment of this supreme desideratum—a leader

without personal interests. Plato sought to guarantee impartiality in his state leaders by making their life communistic. Accepting the same arguments as are thought to justify celibacy in the Catholic priesthood, Plato denied to his guardians wives of their own, children of their own, property of their own. To deal justly with interests, to rule wisely, they needed only such detachment as would render them impartial. Over against Plato's method of destroying interests, historical absolutism has sought impartiality by elevating the leader above society, endowing him with property, honor, leisure, prestige so superior to that of the subjects as would destroy any temptation to take sides or serve selfish ends. Monarchy has thus been made to occupy "a supersocial position which enables it to intervene in the conflict of social interests with the greatest possible impartiality."

The first comment to be made upon these proposed roads to impartiality is that they are never successful. Even modern monarchs, as we all know apart from having it on Bryce's authority, "in general have chiefly relied on and favored the aristocracy who formed their courts, and have allowed the nobles to deal hardly with the humbler classes."[20] Constant discontent and not infrequent revolutions that have marked the passing of absolutism among mankind tell the silent story of leaders who diverted the rights of the many into the coffers of the few. But even if impartiality could be achieved by either route, there is no reason to think that justice could be attained only by such a negative virtue. For impartiality, to be effective, would have to rest on adequate knowledge of the interests involved.

This leads to a word regarding the third expedient noted by Krabbe to insure impartiality—a supreme emphasis upon education of the intellect. If men can be given sufficient intellectual training—so the theory runs—they can be lifted above the solicitation of passion, property and even persons, and can therefore lead wisely because impartially. A logic-machine as leader would not—it is presumed—feel the call to take sides, and democracy in its emphasis upon education has perhaps been in part vaguely moved by this hope.

It is, however, fairly clear that significant impartiality can not be attained even through this avenue. If intellect can be so divorced from interests as to be utterly neutral, it will not feel the worth of interests sufficiently to do them justice when they conflict. Such complete aloofness would certainly seek the monastery for its sphere rather than the presidency. And if "the thinking part of

[20] "Modern Democracies," II: 536.

the nation" does not attain this incapacitating neutrality, there is no guarantee, as Krabbe himself observes, that it "will not apply its thought to the advantage of those interests which concern its own class."

But to make a long story short, we know well enough that genuine impartiality is not attainable; we suspect that were it attainable, it would not be desirable. Certainly the weakness of the intellectual approach to it is indicated in Plato's admission that knowledge of the abstract ideas could not help one find his way home in the dark. Most assuredly in this complex age we no longer solicit, or accept, guidance from men who are, to use the felicitous phrase of John Stuart Mill, "unprejudiced by any knowledge of the facts." Without concrete knowledge, impartiality is worthless for purposes of leadership; and with knowledge significant impartiality is perhaps impossible. It may well be that working compromises by leaders who know, and who serve to the top of their bent, the interests they represent is the nearest approach to this ancient virtue we can now expect in political life. It may well be that democratic leadership so far as it manifests itself in legislation, for example, must in the future be not leadership, but leaderships; *blocs* are already here even in America, and it is practically certain, spite of the superficial indication of the recent election, that they are here to stay; for they mean the presence in Congress of men who really know the interests they serve and who serve them aboveboard. And those of us who see what interests have actually been served by those who professed impartiality are likely to prefer unreserved frankness to underhand betrayal.

VIII

But pointing thus toward further extension of the principle of specializiation, I do not conceal the fact that the dissipation of the grand conception of leadership inherited from authoritarianism into pieeemeal leadership suggested by science gives ground for serious pause. If we are all to become specialized workers, who will make us whole again? Shall we not cease to see life steadily, when we can no longer see it whole? We can no longer fall back with Adam Smith in naïve trust that an "invisible hand" will tie back together what we have dissevered. Herbert Croly did us a real national service in pointing out some years ago that the surest way to ruin all promise of American life is to believe such a specious promise.[21] Nothing seems more certain now than that the God of our fathers, though known of old, is impotent in our hour of democratic need. He has too consistently stood with aristocrats; for

[21] "The Promise of American Life."

his leadership, like theirs, has rested upon prestige and authority. Democracy can expect no help from the celestial court as at present constituted. If democracy is not to go starkly atheistic, as many of its deepest prophets have foretold, it must invent a new God who will be sympathetic with its aims. A democratic God might prove to be the noblest work of man. But such invention is slow work and unsure. Meantime men must apparently take themselves for better or for worse.

The whole quest for social unity *via* a common goal has been tied up with a metaphysics that practically necessitated the conception of leadership that I have been calling undemocratic. The unity of medieval life illustrates this quite patly. Their goal was transcendental, and thus out of reach of natural men. Men must have leaders with knowledge, yes; but knowledge of the goal itself. This meant an esoteric knowledge that not all men could attain. Those who could attain it were in on the ground floor, and were by their good fortune constituted leaders and overseers of others. Unity thus achieved was compatible with the grossest evils, slavery for instance; for in Christ were not the bond and the free made one? Such an arrangement gave clearly enough a unity, but a unity of subordination. But no age seems to be free from such metaphysical illusions. The state absolutists from Rousseau down have substituted for this frankly transcendental goal of medievalism a relatively mundane one, the "real will." But this scheme for unification proves no more satisfactory than the other; for the "real will," being different from both the wish of the majority and even the desire of all, is so inaccessible that most men do not have it and have no way of making it their own. It must be discovered to common men by leaders who gather such dignity and power from their special knowledge of it that they feel then justified in forcing men to be free, as Rousseau put it, or, with Bosanquet, justified in coercing men to serve their own best interests, whether they like it or not.

The insistence on such procedure almost certainly means that whatever unity is achieved by mankind can not be achieved by emphasizing a common goal. We may as well face sooner or later the personal revelation that the right answer to the catechism, "What is the end of man?" is that there is none. Even individual life does not have any one goal; indeed it often has no goal at all. Life has only such ends as we set up for it ourselves; and we have never been able to set up one that anything like all people would recognize as theirs. The only way to get unity through a common goal is to coerce men into our way of thinking, and then camouflage

our immorality by declaring that we punish them for their own good. Verily the rationalizing propensity of us all was incarnated in Cotton's pious declaration that Roger Williams was not persecuted for following his conscience but for refusing to follow it in doing what he knew to be right! This technique for the attainment of social unity must then be given up for good: it is a blind alley over which should be posted, with apologies to Dante, the warning, "Renounce hope all ye who enter here."

But what can not be achieved by the traditional way of emphasizing a common goal seems to be in process of realization through the adoption of a common method of discovering and achieving our own separate goals. By substituting for specious mystic insight the common human power of observation and then by refining raw observation into scientific accuracy through laboratory experiments in natural science, through statistical methods in social science, and through rules of evidence in jurisprudence, the modern age reveals more meaningful unity than has been known among men of any previous period. The only hope for a social solidarity without coercion is continued travel down this scientific road. Whether it will lead us at last to the sociologists' heaven remains an open question. But who will not elect to join the gang that takes the venture when he sees that all other proposed routes have landed the majority of men in the theologians' hell? It may be that discordant interests finally converge as the hub of life is approached. At any rate, this hypothesis strikes me as more promising than any dependence on divine aid or on a unified goal imposed by some pretentious ones. If the fundamental interests of men do not sufficiently converge at the bottom to enable tolerance to bridge the gaps, then there is no adequate basis for social unity. If they do, only increasing knowledge can discover it and only better education can train people to organize their lives upon this insight. A dictated unity is almost as sterile as the pious brotherhood of man deduced of old from the fatherhood of God. So long as this pivotal question of the reconcilability of human interests remains open, the faith of Socrates must be the working faith of the modern man:

> That we shall be better [he said] and braver and less helpless if we think we ought to enquire, than we should have been if we indulged in the idle fancy that there was no knowing and no use in seeking to know what we do not know—that is a theme upon which I am ready to fight, in word and deed, to the utmost of my power.

Leaving unity, therefore, as a highly desirable by-product to emerge from the coalescence of interests, if deeper knowledge can show that they converge, we must turn again to make our final emphasis

upon special knowledge; for without it we can not proceed upon our democratic way.

Leadership based upon prestige and gesturing grandly, though vainly, toward impartiality was the aristocratic ideal. Leadership based upon special knowledge of the facts and flowering toward control of these facts for human ends is the democratic ideal. This newer view is an ideal that breaks the age-old monopoly on leadership and by doing so distributes far and wide the seeds of individuality. A social order in which every man leads where his knowledge justifies and follows where his ignorance compels—that is the way of life which, like the path of the just, shines more and more toward a democratic day.

RADIO TALKS ON SCIENCE[1]

SPUN LOGS

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON, D. C.

SCIENCE consists in learning from nature how to surpass nature. The chemist in particular is never content till he can do something that his teacher can't. In the field of fabrics he has made dyes more brilliant than any to be found in the three kingdoms of nature, animal, vegetable and mineral, and now he is inventing new textiles to tint with them. He beat the indigo plant on its own ground, and carried off the blue ribbon. He challenged a snail to a race, the Mediterranean mollusk that produced the "royal purple" of the ancients, and beat him, for now the chemist is making a better dye out of coal tar and making it so cheap that anybody can afford it.

Now the chemist is engaged in another competition. His rival this time is a worm. He has challenged the champion spinner of the world, one who has, for over four thousand years, held the prize for the finest and most flossy fiber, the silk worm. The worm chews up mulberry leaves and spins out through his mouth a silk thread five hundred yards long. The chemist grinds up logs of wood and spins out by means of his mechanical spinnerets a silky thread as long as he likes, for the machines run day and night and all the week long, throughout the year. And the thread the chemist makes is more uniform in size and substance, for the worm, although he was practising the spinning art thousands of years before man appeared upon the earth, has never yet learned how to produce a perfectly smooth and even filament.

Not long ago I had a chance to inspect a rayon plant, and it was fascinating to watch the process. At one end of the factory spruce logs are floated in. At the other end skeins of glossy yarn are being shipped out. The wood pulp costs about five cents a pound and the synthetic silk sells for two dollars a pound, and more than that when you buy it in the form of neckties, shirts, sweaters and stockings.

And you buy it oftener than you think you do if you prefer to patronize worms rather than men. For nearly two thirds of what

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of Mr. W. E. Tisdale.

seems to you silk comes now-a-days from chemistry instead of the cocoon. But it is not the chemist's fault that he has to disguise himself as a worm in order to market his product. It is rather the fault of the people who have a prejudice for things that are old and familiar, and are unwilling to admit that their fellowmen can make anything as good as the plants, animals or insects that have been longer in the business. The chemist would be proud to claim all his creations, but often he has to stand by while the merchant timidly introduces them to the public as "near" something or "imitation" something, or, what is worse, keeps silent and lets the buyer infer that he is getting the same old stuff instead of something new and often something better.

The dictionary is a heavy and clumsy volume and can not keep up with the swift advance of science. That is why there is no common name yet for the thing that I am talking about, these synthetic fibers made from cellulose, although they have in the last ten years come into such common use. They are often called "artificial silk," or, what is worse, "imitation silk," although they are not the same as silk and should never pretend to be. Last year most of the manufacturers agreed to adopt, and introduce through advertising, a new name, "rayon," for all products of this sort, but some of the makers, those using the acetate process, refuse to accept this general term and stick to their own trade names, such as "celanese" and "lustron."

There are four different processes of making these synthetic fibers and very curiously they are all in actual use. There are now being built in the United States factories for each of the four rival processes.

They are easy to understand in a general way, though to run them so as to turn out a uniform and satisfactory thread is a delicate and difficult operation. They all use the same fundamental material, that is, the woody fiber that the chemist calls "cellulose," though some of them get it from timber and others from linters, the short bits of cotton that stick to the seeds after the long fiber has been picked off. This cellulose is the same stuff as paper is made of.

The first step is to get the cellulose into liquid form in order to squirt it out in a fine jet as the silk worm does. But you know it is not easy to dissolve wood, cotton or paper. Water will not dissolve it, otherwise our floors would be washed away whenever they were scrubbed, or the trees whenever it rained, or our clothes whenever they are cleaned. But certain strong acids or alkalis will serve as solvents for cellulose.

The first of these solvents to be used was nitric acid with which a French nobleman, Count Hilaire de Chardonnet, made an artificial silk in 1884. When nitric acid acts upon cotton it forms what is known as "nitrocellulose" or gun-cotton, the basis of smokeless powder. This can be dissolved in a mixture of alcohol and ether, forming a thick gummy liquid that we know as "collodion" and use as new skin when our natural integument gets scratched off. After the spinning process the nitric acid is eliminated so that the threads are no longer explosive or more inflammable than the original cotton.

The second process for making synthetic silk gets the cellulose into solution by using an alkali instead of an acid, strong ammonia with copper dissolved in it.

The third process also makes use of an alkali, in this case caustic soda, with the addition of carbon bisulfide, a vile smelling liquid that is used for killing gophers. This produces an orange-colored viscous liquid, and the product is known by the trade name of viscose. Four fifths of the synthetic silk is made by this method.

The fourth process employs an acid, concentrated acetic acid, familiar to use in dilute form as vinegar.

In whatever way the cellulose is dissolved the next step is to force the solution by pressure through glass tubes in the end of which are minute perforations, like fine pinholes, from 10 to 50 of them. The liquid squirts out of these pinholes in thin streams which are coagulated into fine filaments by running into water containing something to neutralize and wash away the solvent. These filaments are then caught up by revolving reels, twisted into a thread and dried in skeins. These are packed in ten-pound bundles containing 150,000 or 300,000 yards of yarn, according to the caliber. Each spinning machine in the great room is running off the thread at the rate of forty-five yards a minute.

The final product is brought back almost to its original state, for it is a form of cellulose, except where acetic acid is used which leaves it as cellulose acetate. Rayon is chemically much the same as cotton in composition, but has the sheen of silk and takes dyes even more brilliantly, which accounts largely for its popularity with this color-loving generation. By weaving artificial and natural fibers together it is possible to dye the cloth two colors, for one dye will fix on the rayon and the other on the silk, so bringing out a design invisible in the original white weave. Novel and beautiful velvet brocades are now made by this method.

None of the synthetic fibers is as strong or elastic as natural silk. Their strength is from half to two thirds of the natural when dry,

and much less when wet. Rayon when wet takes up forty per cent. of water and swells and weakens. The wet rayon is only a half or a quarter as strong as the dry, so these artificial fabrics should be handled tenderly while wet. The original strength returns on drying. The cellulose acetate does not weaken so much on wetting, because it does not absorb so much water. Whether this is an advantage or not depends on the advertiser. The viscose people claim that viscose underwear is the best because it absorbs the sweat and so keeps the skin dry and comfortable, summer and winter. The celanese people claim that celanese underwear is the best because it does not absorb the sweat and so is chill-proof and comfortable, summer and winter. You pay your money and take your choice. In most fabrics it is found desirable to mix the rayon with wool, cotton or real silk, and so get both strength and luster.

When this business first started a few years ago, the manufacturers were so delighted at their new-found power to rival silk in luster that they went too far. They turned out satin that was too silky and slick, too glossy and glary. Now they are tempering their ambition for such illustrous fabrics, perhaps in compliance with an improvement in popular taste, and they are now working for softer tones and textures, by using finer filaments, and more of them, in a single thread. Some of the filaments now spun are more delicate than the floss of a silk cocoon. These new forms of the synthetic fiber are softer to the touch and less garish to the eye than the crude products of a few years back.

Manufacturers at first thought it necessary to make their synthetic substitutes resemble silk in sound as well as to the sight. So they fussed about to find a way of giving the new fabrics the "scroop" of the old. The "scroop" is the sound referred to by Poe in his "Raven" as:

> "The silken soft uncertain
> Rustling of each purple curtain."

In those days, when a lady had a silk petticoat she wanted everybody to know it, and since etiquette then required that petticoats, unlike children, should be heard and not seen, she had to rely upon the scroop to impress her proud possession upon the public. But after a process for putting the scroop into synthetic silk had been discovered the style changed and it is no longer considered necessary for a lady to rustle.

A new point in favor of the artificial over the natural product is the discovery that cellulose acetate is more transparent to the ultra-violet rays than wool or silk. Now these invisible ultra-violet rays

are supposed to be responsible for the beneficial effects of sunshine in stimulating the blood to resist disease, so we may expect improvement in public health if the synthetic fabrics become common wear.

Although all the four present processes of making synthetic silk were first developed in Europe, the United States now leads the world in its production and consumption. In the field of science we Americans do not distinguish ourselves on the kick-off but we beat the world in keeping the ball going when once it is put in play. The world's output of these artificial cellulose products for the present year is estimated at about 185,000,000 pounds, and American manufacturers made nearly a third of the total. We may reasonably expect that next year the United States will turn out 74,000,000 pounds, which will mean a 600 per cent. increase in the last five years.

About half of the output of rayon goes now into knit goods, especially hosiery, which is usually combined with cotton, wool or natural silk. For men's hose a mode of knitting called "plating" is commonly employed by which the inside surface of the sock is mercerized cotton and the outside is rayon, so getting the advantages of both kinds of thread.

In braid for dress trimmings the new material has almost entirely ousted natural silk.

Another use of these same cellulose synthetics, this is common but commonly unrecognized, is the thin, colorless, flexible transparent sheets, called "cellophane" or "visca," which wrap your candy or make a window in the envelope that brings you a check or bill.

This protean material seems to be a universal proxy. It can substitute for all sorts of substances. It is now appearing in the rôle of horsehair, Spanish lace, Smyrna rugs, Nottingham lace curtains and furs of various kinds. Sometime it may not be necessary to skin animals to get fur coats and collars, or to steal the silken blanket of the sleeping worm.

PSYCHOLOGICAL REACTIONS DURING DANGER

By Professor GEORGE M. STRATTON

THE UNIVERSITY OF CALIFORNIA AND THE NATIONAL RESEARCH COUNCIL

THERE is a growing interest in emotion. Our intellectual powers —our power to reason, to remember, to imagine, to see—used to receive our almost exclusive attention in the study of the mind. But we now know that an individual's happiness, the happiness of his

family, his effectiveness in business, his mental and physical health, may be seriously influenced by his emotions.

It has long been known that fear or anger may make it possible for a man to perform some unusual feat of strength. Fear or anger may add vigor to his muscles. But fear and anger and excitement are of far wider influence than this.

Let me illustrate this by an experience of an aviator whom I knew personally—a highly intelligent young man who served in the Aviation Corps of the United States army during the Great War. He had two accidents which were of psychological interest. But I shall refer to only one of them, an accident which occurred while he was doing that part of his training which is known as "stunts." He told me:

> Before going up on this particular day I, as usual, examined carefully my controls and found that they were working right. I then went up to a height of about 5,500 feet. . . . My first stunt was a loop, and this I went through all right and straightened out. Then I found that my elevator-control was stuck. I went up on the rise for a second loop, but instead of letting my ship whip-stall and thus run the risk of permanently damaging my controls, I kicked the rudder to the right and dropped into a tail-spin.
>
> It was at this time that a dual personality came into play. I had a rapid survey of my life, not as though I were looking at scenes of my past, but as though I were doing and living them again.
>
> Yet I was conscious at the same time of having to manage my ship. For as soon as I started down in the tail-spin I realized that I had a certain amount of time, and I went carefully over the different controls. I tried the rudder and found that it worked all right. I then moved "the stick," and its movements showed that the ailerons were working, but that the elevator was stuck. I thought that the elevator-wire might have become entangled in the leather slot where the elevator-wire goes through the covering to the outside. So I pushed the stick slowly and steadily forward to overcome such an obstruction. In shoving forward on my stick I felt the tension on my belt, which showed that the control was in some way entangled with the belt. So I reached around and found there the loose end of a wire used to support the triangle of the safety-belt, and which had been left too long and had become entangled in the wire which worked the elevator. I pulled this loose end out, and my elevator then worked perfectly, and I straightened out my ship. I was then at a height of about 1,500 feet, having fallen about 4,000 feet since the accident began.
>
> While I was falling I re-lived more events of my life than I can well enumerate. These were in orderly series, very distinct, and I can not recall that anything was out of its place.

Let me now give an experience of another person whom I know well—a trained scientist and a good observer—an experience which likewise is of great psychological interest. While sitting by the fireside in his home one morning, reading his paper, a little girl standing by the hearth gave a cry and was seen to have her dress afire. My friend jumped to his feet, recalling instantly cases of serious

personal injury by fire among his own circle of acquaintance, where there had been frightful disfigurement for life. The fearful question arose in his mind, "Is a like fate in store for Alice?"—the little girl before him. In an instant he had thought of several alternative things to do—to call for help, to carry the child to an adjoining room where there was water, to smother the flames in a rug, to tear the burning garment from her. All alternatives but this last were rejected, and for reasons; and with great violence but effectiveness, he tore the dress from her, slipping it over the child's head, and she was saved unscathed.

Another scientist whom I know was one day working in his laboratory, when he was the only one in his building. He happened, by accident, to inhale a certain gas that is a deadly poison. Instantly he thought of two means to save himself from serious injury, if not from death. He rapidly tried one of these, and it failed. He then tried the other, which also proved ineffectual; and his condition was rapidly becoming critical. He at once darted to a third alternative which he had in mind, that of reaching a telephone in an office on the floor above the one on which he was working. As he rushed out into the hall and up the stairs, he thought of several persons whom he might try to call, and rapidly made his selection of the one whom he thought would most probably be at home and within reach. The telephone number of his friend stood out, he says, clear, and inches high in his mind's eye as he ran up the stairs. He was just able to gasp a few words of explanation to this friend when be became unconscious. Assistance was hurried to him, and after long and hard labor he was restored to consciousness and his life was saved.

Some of you doubtless have had interesting experiences during a sudden crisis. Whether yours have been like those I have given or very different, I should be glad to have you send me in writing exactly and fully what happened in your case.

For all these experiences help us to understand what is done for us by certain forms of emotion. Sometimes a strong emotion may disturb the behavior of mind and body and make it ineffective. Deep sorrow or disappointment, and in some cases intense fear, may have this effect. It is notorious that in excitement absurd things may be done. When Morgan's men were making their famous raid into the North during the Civil War, their conduct at certain moments was that of men beside themselves. They would rush into some country-store and, in a whirl of greed, seize anything at hand. They would stuff their pockets with horn buttons, start off to southern climes with a string of skates, or with a chafing-dish on pommel, encumbrances only to be thrown to the roadside after some miles of gallop. They behaved, it is said, like boys raiding an orchard.

After the conflagration in Berkeley, California, a year and more ago, I was looking over some of the salvaged possessions which had been brought to a fire-proof building of the university. There, beside a fine mahogany grandfather clock, well worth saving, was a pan half-full of baked apples! So a man's golf or his billiards might easily be upset for the time by an insult offered him, or by the sudden news of some great loss to his business.

But this is not the whole truth, for it is evident that our aviator, during his period of danger, was excited, but he did not lose his head nor lose the full control of his body. He was able to try out his rudder, and his ailerons and his elevator, to see which of them was out of order. He disentangled the wire from his belt, which had become caught in the wire running to his elevator. He was then skillful enough to take his ship out of its tail-spin and straighten it out while there was still some distance between him and the ground. In a like manner my two scientist friends each retained his skilled movements, of standing, grasping or speaking, and so on. And in general, the man who is joyous still knows how to whistle or sing or walk with a sprightly step; and the angry man does not forget the use of language, especially that of vituperation. He is able to walk toward his opponent and threaten him with fist and voice. In some instances emotion makes a man use better what skill he has. On the day after a deep disappointment, in one case I know, a man played a better game of golf than he had ever played before. Often there is a greater variety of muscular movements which are at the disposal of the man who is in an emotional state than of the man who is wholly unexcited. The excited man finds himself able to pass from one kind of act over into another with greater readiness. The changes can be made more rapidly, and there are more things which lie ready for him to do.

The effect upon the muscles, however, is not all. There is also a decided effect upon the intellectual powers.

In the first place there is, in excitement, a repression of ideas and acts which are inappropriate; there is a pushing aside of everything mental which offers no help to meet the crisis in hand. The aviator had something like a series of dreams which ran along beside his practical behavior. Various thoughts that could not help him in his danger were forced aside and became an active system of their own. In a way, this is what happens when soldiers who are wounded do not until afterwards feel any pain; or when David Livingstone in Africa was seized by a lion and his shoulder was crunched and crushed. The shock, he tells us, produced in him only a sort of dreaminess, without pain and without terror, an effect which he compares with that of chloroform.

Besides this setting aside of useless ideas and impressions, there is a speeding-up of the thinking which is useful. My aviator, my two scientists, in their times of danger, were able to think far more quickly than was usual. Each thought with amazing rapidity. But what is more important, each was able to think with remarkable fertility and effectiveness to meet the particular crisis in which he found himself. His judgment worked clearly. The aviator, the two scientists, had to think up and consider a number of alternatives in order to discover how best to meet the trouble each was in. Just as his hands were not paralyzed or clumsy, so his thinking was not paralyzed or clumsy.

So the man in the presence of someone who has injured him is apt to think of many things that he might do or say to injure his opponent in return. The young man in love fairly blossoms with ideas as to ways in which he may express his affection or gain success over a rival. Turgeniev, the Russian writer, when asked in his latter years why he was not writing as much as before, said that he was too old to be in love, and that he had found that unless he were a little in love he could not write.

Thus certain kinds of emotion or certain phases of all emotion render us valuable service. For when an individual is stirred he finds himself for the time being on a new level of behavior, both of mind and body, and is able to meet his crisis with a more complete array of his powers and with a better organization of them. And let me repeat that these powers are not those of his muscles only but are of his entire personality, both of body and of mind.

THE AWAKENING IN SCIENCE

By Dr. H. E. HOWE
WASHINGTON, D. C.

The desire of the modern scientist to have the non-technical public acquainted with his work is one of the striking differences between to-day and yesterday. In the earliest times scientists encouraged the public in the belief that their work was one of mystery and legerdemain. This gave rise to the odd codes and symbols of the alchemists, to the use of Latin in medicine and to the adoption of symbols and formulas in pharmacy, well calculated to keep secret from the public the real composition of the remedies prescribed. Nowadays, it is true, scientists use a sort of shorthand, but no serious effort has been made until lately to have the public appreciate that modern formulas, symbols and abbreviations are used for

convenience only and are really an easily understood system of abbreviation rather than an undecipherable code.

One of the factors influencing this change in the attitude of the scientist is the realization that in many respects science has progressed beyond the industrial application of some of its newly discovered facts and that the arts have lagged behind until the public fails to appreciate the significance of scientific work. The public generally fails to support fundamental research on an adequate scale, therefore, not so much from a lack of sympathy as from a lack of understanding of its significance.

The chemists were among the first to realize the necessity of encouraging the general public to become better read in science, to appreciate the cultural value of its study and to learn that many stories of accomplishments in the field of chemistry were more engaging than fiction. Their purpose is not to encourage large numbers to become chemists, but to induce still greater numbers to know a little of the relations of science to our everyday affairs. The ever-increasing numbers in our high schools suggested the possibility of obtaining a greater familiarity on the part of the public with science by starting with these students. Consequently, the American Chemical Society has been enabled through the beneficence of Mr. and Mrs. Francis P. Garvan, of New York, to offer substantial prizes for the best essay on each of six chosen subjects, these prizes being available for every state, the District of Columbia and the extra-territorial possessions of the United States, taken as a unit. These subjects are: "The relation of chemistry to health and disease," "The relation of chemistry to the enrichment of life," "The relation of chemistry to agriculture or forestry," "The relation of chemistry to national defense," "The relation of chemistry to the home" and "The relation of chemistry to the development of an industry or a resource of the United States." The winners in these states compete for four-year scholarships at Yale or Vassar, which are awarded as national prizes in these same groups. In the 1923–24 contest the winners were located as follows: Centralia, Washington; Santa Rosa, California; Hartford, Connecticut; Commerce, Georgia; Dallas, Texas, and Phoenix, Arizona.

Furthermore, in the 1924–25 contest large cash prizes are offered for the best essays on the same subjects prepared by undergraduates in our colleges and universities. Thousands of sets of books have been distributed gratis to high schools, colleges, libraries and individuals interested in education in connection with this effort, and a new volume has been especially prepared, dealing with instances of chemistry in the service of industries. Complete information regarding the current contest may be had by addressing the

secretary of the Prize Essay Contest, at 85 Beaver Street, New York City.

Another conspicuous effort to give authentic information to the public is the News Service of the American Chemical Society, which distributes without charge stories of the progress of science. That the public appreciates this information and prefers it to the sensational stories at one time circulated is evidenced by the fact that the space devoted to such scientific announcements in the daily press has increased twenty-five fold in the last six years.

Still another successful effort is that of Science Service, an organization controlled by the National Academy of Science, the National Research Council and the American Association for the Advancement of Science. Science Service, endowed in order that a part of its overhead may be assured, prepares on regular schedules popular but authentic stories of new discoveries in all the fields of natural science and distributes them to newspapers throughout the country.

The public has found science so interesting that the established publishers are providing a great number of books written in non-technical language covering most of the natural sciences. There are still too few of these informing volumes, but with the growth in popular demand we may confidently expect our best scientific authors to engage in the preparation of accounts of their work, written from the standpoint of the general reader.

In many parts of the country broadcasting stations, appreciating the educational value of science stories, are making it possible for university and other groups to go on the air with short accounts of what has been done or is in progress in scientific laboratories and industries founded upon science to improve public welfare. The same universities are even giving specified courses in scientific instruction by means of the radio.

We may look forward to a not far distant time when unfamiliarity with the progress of science will be looked upon as an evident fault in education and training, even as we now look upon a lack of acquaintance with the classics, with history or current events. It is fortunate that so many agencies are at work to assist the non-technical reader and the general public, and you are missing something worth while if you fail to make the most of the opportunity.

The opportunity to take and hold the lead in industry as well as in science has not been overlooked in America, where to-day a larger sum of money is being devoted to research than at any period in our history. Indeed, it is doubtful whether any nation is expending a greater amount of time, effort and money in scientific pursuits than is the United States. We commonly think of scientific research

as an activity pursued principally in the laboratories of educational institutions and in the various bureaus of our federal and state government departments. It is true that most of our fundamental work is carried on under such auspices, but it is noteworthy that in recent years great industrial establishments have seen the necessity of pursuing such work on their own account in order that their material progress may not be arrested. Research has also been found to pay such industries in more indirect ways, as, for example, the fact that a better grade of employees is attracted to an institution where the scientific spirit prevails, that the business man himself finds a new interest in problems open only to scientific attack, and that there is a feeling of confidence in the future where research is one of the potent factors in business not to be found in those industries relying solely upon past experiences.

There are approximately 250 educational institutions in the United States in which research in physics and chemistry is being carried on. There are somewhat over a thousand men and women actively engaged in this work and well over a million dollars devoted in these laboratories to research activities. Accurate statistics regarding industries are not available, but it is certain that a sum approximating twenty million dollars is spent in an average year upon research, control and developmental work involving physics and chemistry, to which should be added a sum of several hundred thousand dollars for work spent in the biological sciences, not including medicine. The fields of biology, particularly biological chemistry and several aspects of the medical sciences, offer such great opportunities for the well-trained men in research that a constantly increasing sum of money is being judiciously spent in such endeavors, but figures are not available. Add to this sums spent in the governmental laboratories—federal, state and municipal—and we shall find a very large sum of money being invested annually in the search for truth to be ultimately applied to the welfare of the nation and of the race. The last decade has seen an increase of approximately 30 per cent. in the appropriations in America for research activities, and notwithstanding this increase there is an ever-present need for large additional sums for the support of scientific work.

Thanks to unparalleled natural resources, we still seem able to live largely upon our capital rather than our income. But far-sighted men and women are beginning to appreciate the necessity for not only confining ourselves to the income from our capital, but actually laying aside a surplus for the future. This means that we must learn to make better use of all sorts of natural resources, that we must develop methods for utilizing low grade materials,

that there must be greater progress in the synthesis of products that the laboratory may supplement the diminishing supplies of substances heretofore found only in nature and that we must continue our efforts in search of the ultimate structure of matter to the end that with such information our manufacturers in all fields may proceed with the greatest assurance of obtaining the utmost in yield and quality.

The fact that applied science, which every one can surely appreciate, always depends upon facts won through abstruse research explains the necessity for the popularization of science. At present the public is not sufficiently informed of this relationship to support the research worker to an extent which makes it possible for him to lay the foundations for processes and devices which in turn provide us with safer, longer and more enjoyable living. Those who work in pure science often seem to the public to be far removed from everyday problems, but you, who are the public, need consider but for a moment to realize what our present-day civilization owes to research in the fundamental sciences.

THE ELECTRICITY OF THE AIR

By Dr. S. J. MAUCHLY
DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON

About one hundred and seventy-five years have elapsed since Benjamin Franklin proved by his famous kite experiment that lightning is identical with the electricity of our laboratories. From that time forward well into the present century, the subject I have chosen would have suggested, to most people, a discourse on lightning or thunder-storm electricity. But to-day, with a radio receiving set in nearly every home, we have all become more or less familiar with the fact that radio transmission and reception are in large measure dependent upon the electric conditions of the air even during the fairest of weather. Time will not permit me to attempt a discussion of all the electrical phenomena of the air, and I shall, therefore, confine my remarks to the silent and unseen electrical phenomena which are continually taking place in the air surrounding us, while we work or play or sleep. I shall endeavor to give briefly some of the most interesting and important of the known facts regarding this so-called "fair-weather electricity" and occasionally a bit of theory regarding them.

For example, in the space surrounding the earth and occupied by the air there is an electric condition called potential which some-

what resembles the pressure in a water main. However, this force differs from ordinary pressures in water or air in that it affects only bodies which are electrically charged; that is, it acts as a motion-producing force on particles of air, dust, drops of water, etc., which are electrified but does not affect those which are neutral or uncharged. Technically this is referred to as the earth's electric field, and the volt with which every one is more or less familiar is the unit used in measuring its strength or intensity. But the air-potential normally increases with height above ground, and it is, therefore, customary to refer to the earth's field as being so many volts per meter or volts per foot to show the amount of change in potential for a meter, or for a foot, of change in height. For our present purpose, however, we shall in most cases be concerned only with the potential at a given point.

The strength of the earth's electric field under average fair-weather conditions is such that the electric potential of the air at the height of a man's head is usually several hundred volts greater than it is at the ground beneath his feet. Or, in other words, out in the open, away from buildings and trees, the difference in electrical potential between the ground and a point five feet above ground is usually somewhat greater than the difference of potential between the lead wires of the ordinary house-lighting circuit. Combining this experimental result with well-established electrical theory leads us to the startling conclusion that the entire earth is electrically charged to a potential of many millions of volts. This at once raises a question as to why we are not subject to injury or discomfort as a result of living in such a strong electric field. I will return to this point again later, but for the present I may say that, electrically speaking, our bodies really form a part of the earth and our position is somewhat similar in this respect to that of birds sitting without harm upon a high-tension electric wire. Our observations also show that at a distance of say ten feet above ground the potential of the air is twice as great as at the five-foot height, etc., and that a free balloon at an elevation of a mile may be at a potential fifty thousand or more volts greater than at the ground.

At many observatories in various parts of the world the electric potential of the air is continuously recorded by automatic instruments. Three such observatories are maintained by the Carnegie Institution of Washington, one being in the District of Columbia, another at Watheroo, on the plains of Western Australia, and a third at Huancayo, in the Peruvian Andes. Records so obtained show, in all cases, that the electric potential of the air where the instrument is placed changes continuously throughout the day and

that the daily change, at any given locality and time of year, is very similar from day to day. In some regions the daily change is much the same throughout the year, but in many localities the average daily change during the winter season differs very much from the average daily change during the summer.

The Department of Terrestrial Magnetism of the Carnegie Institution of Washington is making careful and extensive studies of the changes in the earth's field during the day, during the year and from year to year, based on continuous air-potential observations in all parts of the world. One of the most striking results thus far obtained is that the chief daily maximum or high point tends to occur everywhere at approximately the same instant. Thus, for example, the highest potential occurs shortly before noon in Washington, in the late afternoon or evening in most parts of Europe, and between midnight and morning in Western Australia and Eastern Asia.

It is further found that, at most stations in both the northern and southern hemispheres, the average value of the atmospheric potential for a given place and at a given height above ground is greater during the months from October to March, inclusive, than during the remainder of the year, although there are several regions where the reverse seems to be true.

The origin of the electric charge on the earth and of the resulting electric field is not known. And, as if to add to the interest and to the difficulty of finding a suitable explanation, it appears that there are gradual changes from year to year in the atmospheric potential which are in close relation with observed sunspot changes. Thus, in trying to explain the existence and variability of the earth's electric field we must take into account not only the entire earth but also conditions on the sun.

Another matter of great importance in atmospheric electricity is the electric conductivity of the air or its ability to carry an electric current. For, although the air is one of the best-known insulators, it is far from being a perfect insulator. As is well known, air consists almost entirely of small particles, called molecules, of nitrogen and oxygen. While most of these molecules are electrically neutral, there are always a few—only a small fraction of a per cent. of the total number—which are charged, some positively and some negatively. Those positively charged are called positive ions and those negatively charged negative ions. Now positive and negative ions attract each other, and whenever two oppositely charged ions meet their charges neutralize and they again become ordinary uncharged air particles. Thus, the ions of the air are constantly disappearing, and the air would soon be in a neutral or un-ionized state

unless a new supply of ions was constantly available. However, new ions are being formed at such a rate that a cubic centimeter of air under ordinary conditions usually contains about one thousand free or uncombined positive ions and, roughly, the same number of free negative ions, that is about sixteen thousand of each kind to the cubic inch. The process by which these ions or charged particles are produced is somewhat too complex for description at this time. In brief, it may be said that the small amounts of radium and thorium naturally present in the air and the direct action of sunlight are largely responsible for their continued formation. From observations over the oceans and in balloons it appears that a so-called "penetrating radiation" may also be one of the important causes of the ionization of the air, although the nature of this radiation is not well understood.

Under the action of the earth's electric field the positive ions of the air normally travel toward the ground and the negative ions in the opposite direction at a rate of nearly an inch per second. Consequently, under normal conditions, there is everywhere an electric current passing from the air into the earth. I have spoken in terms of thousands and millions of volts and must, therefore, hasten to prevent the impression that our lives may be endangered by the current thus produced. In fact, if the entire human race were collected out in the open at one time the total flow of current from the air to the ground through the bodies of the assembled multitude would be less than that required to operate an ordinary reading lamp. Nevertheless, small as this current is at any one place, its total amount over the entire earth is by no means negligible and is estimated to be at least one thousand amperes. Moreover, although the earth is, as already stated, charged to a potential of many millions of volts, 90 per cent. of its charge would be neutralized within ten minutes by this air-to-earth current if there were no source of replenishment.

Many investigators believe that the sun is the source of this replenishment, and various experiments have been made to test this point. However, no proof has yet been found that electricity from the sun actually gets down into the earth. It has been suggested also that lightning discharges may be the source of replenishment, since such discharges, while comparatively infrequent in a given locality, are probably taking place almost continuously if we consider the whole world. However, some lightning discharges bring positive electricity to the earth, while others bring negative, and it has not yet been shown that the negative discharges are in excess of the positive by an amount sufficient to counteract the constant downward current of one thousand or more amperes.

All our direct knowledge of the ionization of the air is necessarily limited to those parts of the atmosphere which have been reached by balloons. However, from purely theoretical reasoning, investigators have long believed the air at some very high level to be highly ionized and to have an electrical conductivity enormously greater than that of the air in which we live. Observations in balloons and on high mountains do, indeed, show that the air gradually becomes a better conductor of electricity as higher levels are reached.

Most radio investigators now believe that a knowledge of the electric conditions of the upper air is of the utmost importance in matters concerned with the improvement of radio communication. Unfortunately, we have at present no observational means for directly exploring the upper air at the heights which are here involved. However, there are promising indications that valuable information concerning the upper regions of the air may soon be obtained by the correlation of indirect evidence. For example, by the use of selected radio wave transmissions in particular directions, at particular times and on particular frequencies, the radio engineer is now able to obtain much valuable information regarding the electrical conditions at elevations far beyond the reach of direct attack by the student of atmospheric electricity. Thus, the correlation of effort between workers interested primarily in the study of atmospheric electricity and those whose chief interest lies in the field of radio communication will certainly contribute to the solution of outstanding problems of common interest.

BLASTING A NEW FACE ON NATURE

By Dr. CHARLES E. MUNROE
NATIONAL RESEARCH COUNCIL

During a recent visit to our splendid Military Academy at West Point, New York, my hosts, among other attentions, motored me over the recently opened Storm King Road which rounds the "Klinkenberg" or "Echo Mount," high up on its steep side and leads on to that country of legend and mystery made famous by Washington Irving in Rip Van Winkle and other tales.

With the rapid multiplication of automobiles, propelled by the explosion of explosive mixtures within their cylinders, congestion on all highways has become marked; especially on those in and about great centers of population. In the valley of the Hudson there was but a single highway, located on its eastern bank, leading to

Albany and at times automobiles, notwithstanding their capacity for speed, have been compelled to move at, practically, a snail's pace. It was obvious that a highway on the west shore would relieve this congestion, but there stood the Klinkenberg, one of the highest peaks of the group, like a "storm king" at the northern "Gate to the Highlands." A mass of rock, many hundred feet in height, rising abruptly from the bank of the river, and bordered with deep ravines, such as Big Gully, it barred the way. By means of high explosives, it was a comparatively simple thing to blast out the face of this mount so as to provide a ledge for the roadway, rock for building the parapet and retaining walls, and material with which to fill the ravines to be crossed.

By the aid of explosives, roads, many of great length and passing through rugged mountainous regions, have been and are being built all over our country, giving easy access to all parts of it, and opening large areas of land to the occupancy and use of our rapidly growing population.

Among the more important of these roads, one might name the Columbia River Highway, four hundred miles in length, passing through the Cascade Range of Mountains and disclosing most magnificent scenery; the Pacific Highway, now paved from the Canadian to the Mexican borders, and the Lincoln and Lee Highways, which, when completed, will join the Atlantic with the Pacific. The Needles Highway of South Dakota penetrates the very heart of the hills and opens to public view fourteen miles of unusual needle-like granite formation of unforgettable beauty—a scenic paradise. The federal government is distributing many million pounds of surplus war explosives for use in building roads in each of the states.

It was in other avenues of transportation that the value of explosives was earliest recognized. The first application of gunpowder, of importance in this field, was probably at Malpas, France, during 1670–1681, in the construction of a tunnel 510 feet long, on the Languedoc Canal. The latest, and by far the greatest, example in this field is the Panama Canal, where explosives were used on the most extensive scale ever known in canal construction.

With the invention of the locomotive by George Stephenson and the development of transportation by rail the advantage of easy grades and direct routes was emphasized. From the beginning railroad builders have sought to remove obstacles and not to evade them. Hence from the beginning they have employed explosives with which to cut and fill, or, where the overburden was large, to pierce. The first railroad tunnel in the United States (driven in 1831 to 1838, on the Alleghany and Portage Railroad in Pennsylvania) was 901 feet in length. During 1854–1876, the Hoosac Tunnel, four and

one quarter miles in length, was driven through Hoosac Mountain, Massachusetts. Dynamite was extensively used in this work and a factory to supply the nitroglycerin was built at North Adams. During 1857 to 1872, a tunnel, 7.6 miles long, was driven through Mt. Cenis, and since then other tunnels have pierced the Alps. To-day work is in progress on the Moffat Tunnel, 6.09 miles in length, to pierce the Continental Divide. It is to replace the twenty-three-mile route by which the Denver and Salt Lake Railroad now surmounts the Rockies, reduce the lift on all that is moved by 2,400 feet and eliminate the tremendous expense and numerous delays due to the heavy snowfalls encountered at this altitude. It is estimated that over 3,000,000 pounds of high explosives and 325,000 detonators will be required in carrying out this project.

The longest of these transportation tunnels is short when compared with the thirty-one miles' length of the Croton Aqueduct, or the Shandakin Tunnel in New York's more modern system, 18.1 miles long, and said to be the world's longest continuous tunnel. In irrigation and water supply projects explosives play an essential part, not only in the driving of tunnels and general excavation work in difficult earth and rock formations, but also in the building of dams. For it is by their use the rock for the base and the materials for the cement with which the concrete is compounded is blasted from the quarries and comminuted to workable size. At certain localities it has been proved feasible, by means of explosives, to blast large masses of material from the adjacent banks with which to dam the stream.

These dams, like the Roosevelt and Wilson dams, cause large areas of country to be submerged and artificial lakes to be formed. Through the damming of the streams in the Catskills, to form the Ashokan and the Schoharie reservoirs, storage for 128,000,000,000 gallons of water has been secured in the first, and for 20,000,000,000 gallons in the second mentioned reservoir. By such construction in inhabited regions large areas of farm lands, long occupied as homes, and even villages disappear.

Ocean transportation also makes its demand on explosives, especially in the removal of obstructions which menace the safety of vessels, and this demand becomes the more urgent with the increase in size, draft and speed of vessels. In the latter part of 1885 the residents of New York City were thrown into a state of consternation by learning that Flood Rock at Hell Gate in New York Harbor had been mined, charged with some 289,000 pounds of rack-a-rock and dynamite, and was to be blown up, and all manner of predictions as to the damage that would result, even to the entire destruction of the city, were made. The mine was fired on October 10,

1885, by little Mary Newton, daughter of the chief of engineers, United States Army, but, beyond the disintegration of Flood Rock, the production of a fountain of water, over the area of the rock, which rose in some parts to a height of 160 feet, and a small tidal wave, no other obvious effects resulted. It did, however, give rise to an earth wave which was recorded as far away as Albany, New York, to the north, and Cambridge, Massachusetts, to the east. Through observations on big blasts like this, Mallet, Milne, Omri and other experts have learned much as to the methods of transmission and behavior of earthquake waves.

The 289,000-pound charge used in demolishing Flood Rock was then the largest charge of explosives ever fired in a single blast, and it remained unchallenged until during the Great War the Germans started, just after the first battle of Ypres, the practice of mining the trenches. The British organized a special corps to meet this form of attack, and in June, 1916, some 227 mines were sprung on the British front. This form of warfare culminated on June 7, 1917, when the British sprung a mine at Messines Ridge charged with 933,200 pounds of high explosives. This was a tremendous amount, but it was distributed in twenty charges, over a front of approximately 14,500 yards in length and the explosions occupied approximately thirty seconds, so it is hardly on "all fours" with Flood Rock. Referring in his "Memoirs" to this blast, General Ludendorff says: "The moral effect of these explosions was simply staggering."

More spectacular and hazardous was the blowing off of the top of the Col di Lana, a cone-shaped peak in the Dolomite Alps, and a pestiferous stronghold of the Austrian army (as planned and executed by Prince Gelasio Caetani, Italian ambassador to the United States, and his associates), with some five tons of explosive gelatine, by which the Italians captured that front.

The United States is perhaps the largest manufacturer and user of explosives. The Bureau of Mines reports that 529,727,859 pounds were used in this country last year. Also this is the country of large blasts. For years charges of one hundred thousand pounds have not been infrequent. On February 16 last, 301,200 pounds were fired in the Lakeside quarry of the Southern Pacific Railroad, forty-seven miles west of Ogden, Utah. On April 27, last, 364,000 pounds of dynamite were fired at the quarry of the Blue Diamond Materials Co., Corona, California. This was probably the largest movement in real estate in California since the earthquake and this charge of explosives now holds the world's record.

INSECTS AND HUMAN WELFARE

By Dr. E. P. FELT

STATE ENTOMOLOGIST OF NEW YORK

INSECTS are to be found almost everywhere. Under certain conditions they cause serious losses to man. They not only destroy crops and other property, but function as the active agents in spreading death in some of its most horrible forms.

The vast numbers of insects, the great variations in species, the ready adaptations to environments, the enormous prolificacy are all factors which place insects among the most dangerous enemies of man. There are some who profess to see in insects a real menace to the future welfare and development of the human race. It is certainly a question which should receive careful consideration and one can not be too cautious as to the conclusions drawn from available facts.

In passing, it may be well to recognize the fact that many insects are decidedly beneficial, directly or indirectly. The flower-visiting bees and flies in particular make possible the thorough fertilization of fruit blossoms and in that way alone add greatly to the material prosperity of man. The honey and the wax of the honey bee are well known and have been prized from ancient times. The silkworm, the cochineal insect and the lac insect all make contributions to our well-being. There are, in addition, long series of predaceous and parasitic insects which, by destroying their associates, keep potentially injurious species from becoming destructive. The balance of nature in relation to insects is so delicately adjusted that under normal conditions only a very few species become sufficiently numerous as to be destructive, in spite of the fact that a very large proportion of the myriad species depend for sustenance directly upon vegetation.

It is well known that insects levy a high tax, as it were, upon the products of farm and forest, the loss by no means ceasing when the crops are harvested and the trees manufactured into lumber and wood products. It is easy to point to the enormous losses caused by the Hessian fly, the cotton worm and the boll weevil of the south, the spruce bud worm, the bark beetles of the genus Dendroctonus in the Appalachian and western forests and the more recently introduced gipsy moth and the European corn borer of the northeastern United States. All these and a number of other insects cause or have caused enormous losses to our products.

The outstanding depredations have resulted from combinations unusually favorable to the development of insects. The Hessian fly, for example, finds ideal conditions in the extensive wheat fields of this country, provided sowing is early enough to permit an abundant infestation in the fall. The extensive cotton fields of the south afford a paradise for the cotton worm and the boll weevil. The large areas of mature or nearly mature timber in our wooded sections have met, in a most admirable manner, the requirements of certain bark beetles. The spruce bud worm, reveling in the abundance of balsam in our northern forests, periodically turns to the less acceptable though much more valuable spruce and then causes tremendous losses. The gipsy moth and the European corn borer have found in this country comparative freedom from insect parasites and a superabundance of plants adapted to their needs.

It is significant that over half of our more injurious species have been introduced from abroad. The establishment of species from other countries is probably still going on in spite of the fact that quarantines have never been more numerous or better administered. Furthermore, there are presumably in this country at the present time a number of recently introduced insects which, in the course of ten to twenty years, may assume the status of major pests. That is, they are existing at the present time in such small numbers as to escape notice. The gipsy moth, for example, existed in New England for some twenty years before it became sufficiently abundant to attract attention. Generally speaking, in the case of introduced pests, we may expect a period of acclimatization and adaptation accompanied by little or no injury, then there may be enormous multiplication and very serious losses extending over a series of years and this in turn be followed by a gradual decrease in the numbers of the pest and the establishment of what might be considered the normal for this country.

These introduced species disturb, to a greater or less extent, the relations existing between other insects and their food plants, though in time this may be corrected, to a very considerable extent at least, either through the development of native parasites or the introduction of such forms from the native home of the pest. Present conditions in this country are favorable for the appearance of new pests with accompanying losses, yet these latter will presumably be offset, to some extent, by a decrease in the numbers and ravages of injurious species now at the height of their destructiveness.

A change in habits or distribution in a country is also responsible for the development of injurious insects. The Colorado potato

beetle, originally living upon the bull thistle in the Rocky Mountain region, found the cultivated potato much more to its liking and has gradually established itself throughout most of the United States. The Mexican bean beetle of the southwest appears to be following in the footsteps of the Colorado potato beetle, though it has spread more rapidly and is seriously injurious to several important crops.

The extensive depredations alluded to above are the logical outcome of changes in the flora, due to the extensive planting of crops or the allowing of trees over large areas to reach a mature and most attractive condition for certain borers. The assumption that such ravages are likely to increase in the future is based upon a presumed continuance and accentuation of these conditions. This is hardly creditable to the discernment and foresight of those responsible for the development of our agriculture and forestry. Nature is teaching in a most practical way, namely, through economic losses. It is fair to assume that the pupils, the men of today and to-morrow, are learning these lessons and gradually bringing about a modification which will result in less extensive losses from the work of destructive insects. In the case of field crops, this may sometimes be accomplished by modifications in agricultural practices or the growing of more resistant or less attractive varieties. The adoption of direct control measures is entirely feasible for the valuable fruits, a practice which has become very general in the last generation, and is now becoming increasingly prevalent in the case of ornamental trees of our streets, parks and more pretentious estates. Material progress is to be noted along these lines and in the course of another generation or two we may look for marked benefits as a result of systematically avoiding conditions favorable to the development of insect pests.

There is another factor which should be taken into consideration. The inevitable increase in the population of this country means a higher, more intensive type of agriculture and a gradual though inevitable reduction in the extended areas devoted to special crops. This results, irrespective of intelligent efforts to check insect depredations, in the gradual development of conditions less favorable for an abnormal multiplication of insects through a diversified agriculture with its smaller cotton and corn fields and more carefully managed forests.

The comparatively recent discovery of the part played by insects in the dissemination of disease has given ground for serious apprehensions and in some cases, at least, individuals have failed to realize that death by yellow fever, typhus or typhoid is no more

horrible when the agent is known than before. They have failed to recognize the fact that with knowledge there comes, almost inevitably, a more general adoption of preventive measures. These discoveries, while making certain insects more abhorrent, really decrease the probabilities of wholesale loss of life through such agencies. It is impossible to believe that, under present conditions, wholesale decimation may result from insect-borne diseases. The black death of the middle ages, with its paralyzing loss of life, occurred at a time when the louse dwelt with royalty and was by no means a stranger to the common herd. The louse still exists. During the great war, the stage was set for a tremendous outbreak of typhus and other deadly infections carried by this pest. The signs of the times were read correctly and the leaders of men turned their efforts, in part, from slaughtering each other to fighting a common foe. They won, but not before thousands of lives had been lost in certain areas. Much the same might be written of yellow fever, one of the most dreaded and deadly scourges in the early years of this country.

The diseases mentioned still exist, the insects are still to be found, but wide-spread epidemics are impossible under present-day conditions, because our medical men have learned that these insects without the infections are practically harmless. Well-directed efforts toward keeping the numbers of these disease carriers down to a minimum and the safeguarding of the remainder from infection have resulted in liberating mankind from a number of most deadly scourges and this under conditions which were far from favorable in many cases.

There should be no minimizing of the destructive and dangerous rôle played by insects. On the other hand, we should take account of what has been accomplished and realize that the destiny of the human race will be decided, in large measure at least, by the energy and intelligence brought to bear upon the numerous and exceedingly important problems forced upon us by the myriads of insects found at every turn. We should not forget that, although insect increase is theoretically illimitable, practically speaking, there are bounds which even they can not pass. There is a balance or an equilibrium in nature which is found throughout the entire sequence of animal and plant life and whenever this balance is disturbed there is likely to be a great increase in the activities of some agency, accompanied by a trend back to normal. Practically speaking, an insect or a plant disease can not exterminate its host, though under certain conditions there may be a close approach thereto over limited, though possibly extensive areas. The plant-

feeding insects are subject to attack by insect parasites, numerous other natural enemies and in not a few cases fall victims to adverse climatic or other physical conditions. The same is true in a general way of those which disseminate disease. Widespread fluctuations are to be expected and, viewed from the standpoint of the individual, limited to a restricted area, these may be catastrophic in extent. In the broader sense, however, these are only billows upon the sea of life. They can not rise beyond a certain level and inevitably must drop to or below a line which may be designated as the mean of equilibrium.

SHADOW BANDS

By Professor HARLAN T. STETSON
ASTRONOMICAL LABORATORY, HARVARD UNIVERSITY

Few phenomena outside the solar corona itself probably excited more curiosity at the eclipse of the sun of January 24, 1925, than the so-called shadow bands.

Many observers who watched for the onrushing shadow of the moon and failed to glimpse it because of a poor vantage point for observation were fully rewarded with the extraordinary display of shadow band phenomena. This curious display of shimmering ripples of light and shade to be observed shortly before and immediately following a total eclipse was seen and described as early as 1820 by Goldschmidt and has been identified by later observers as more or less parallel lines of shadowy waves in rapid motion across the landscape. At some eclipses these alternate bands of light and shade have appeared to be narrow and at other times broad. The distance apart between the bands has likewise been observed to vary with different eclipses and in different localities. The velocity of these moving bands moreover varies greatly in speed and direction and has been thought to be dependent upon the wind. On certain occasions at total eclipses no shadow bands whatever have been seen either before or after totality. The freakish character of the will-of-the-wisp phenomenon has long been thought to be due to atmospheric disturbances. This interpretation seems to be substantiated by the additional fact that shadow bands at eclipses do not appear to differ greatly in character from the shadow bands which may be observed from a narrow or point source of light shining through a layer of air which is agitated by convection current rising from a heated body between the illuminated source and a light background. The bands as displayed at the last eclipse were quite generally seen and were especially conspicuous on account of the fresh layer of snow which blanketed the eastern states on the morning of the eclipse. Furthermore, the anticyclonic character of the weather was particularly favorable for a turbulent condition of the atmosphere so favorable to the appearance of these bands.

For one to fully appreciate the fairly simple condition under which these bands arise it is only necessary to watch the brighter stars on any night, especially on one following a violent change in meteorological conditions and observe the incessant scintillation or twinkling which takes place as the tiny pencil of light from the restricted source is wafted about hither and yon while traversing the

perturbed ocean of our own atmosphere. Were the light from a star sufficiently brilliant, these irregular flutterings could readily be seen projected on any white surface. Were the star a narrow slit in place of a point source these patches of light and shade would be drawn out into roughly parallel bands.

When, therefore, with the approach of totality the sun's brilliant disk is narrowed down to a slender crescent subtending but a few minutes of arc, we have the stage set for shadow bands of sufficient intensity to be seen on any light surface, such as pavements or the walls of buildings. Many explanations of shadow bands have been written, and artificial shadow bands produced by laboratory experiments. More than forty years ago the bands were produced artificially and described by W. H. Pickering,[1] the apparatus concerned being a searchlight set on the roof of the Physical Laboratory at Harvard University and directed towards a white screen erected on the Harvard Observatory, somewhat less than a mile distant.

More recently the production of shadow bands by searchlight has received careful study by Mr. P. R. Bassett,[2] research engineer of the Sperry Gyroscope Company, who, working with a 60-inch searchlight with a beam candle power of 800,000,000, observed at a distance of two miles conspicuous displays of shadow band phenomena exhibiting nearly all the general characteristics, as to motion, spacing and irregularities, which he observed in the case of the total eclipse of last January 24 from a station at Stratford, Connecticut.

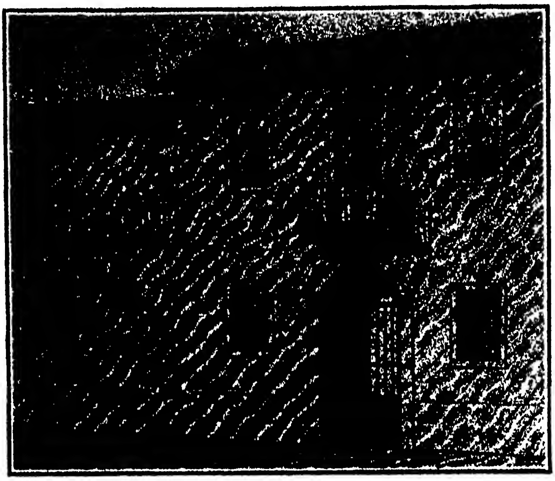
Because of the transient and elusive character of shadow band phenomena, all attempts at photographing them prior to the eclipse of 1925 have been futile. For the eclipse of 1923, Professor Douglass, of the University of Arizona, had devised a special form of camera with which he had succeeded in obtaining satisfactory photographs of artificial shadow bands, and with which he had hoped to catch the first impressions of the true eclipse bands. The limited staff of the party at his station, however, was not sufficient to put into operation the shadow band camera in addition to other apparatus demanding first consideration.

It was at the instigation of Professor Douglass that the photographing of shadow bands was added to the program of our party from Harvard University. We took for our station a location near the Van Vleck Observatory at Middletown, Connecticut, and had for our primary object the measurement of radiation from the solar corona with a vacuum thermocouple, collaborating with the Bureau of Standards for this purpose.

[1] *Harvard Observatory Annals*, 18: 95.

[2] *Popular Astronomy*, 33: 232.

The operation of the special shadow band camera was made possible through the prompt shipment of the outfit by Professor Douglass from Arizona to our station at Middletown, and the courtesy of two additional members of our party, Mr. D. W. Mann, mechanician of the Jefferson Physical Laboratory, and Mr. Kenneth Gell.

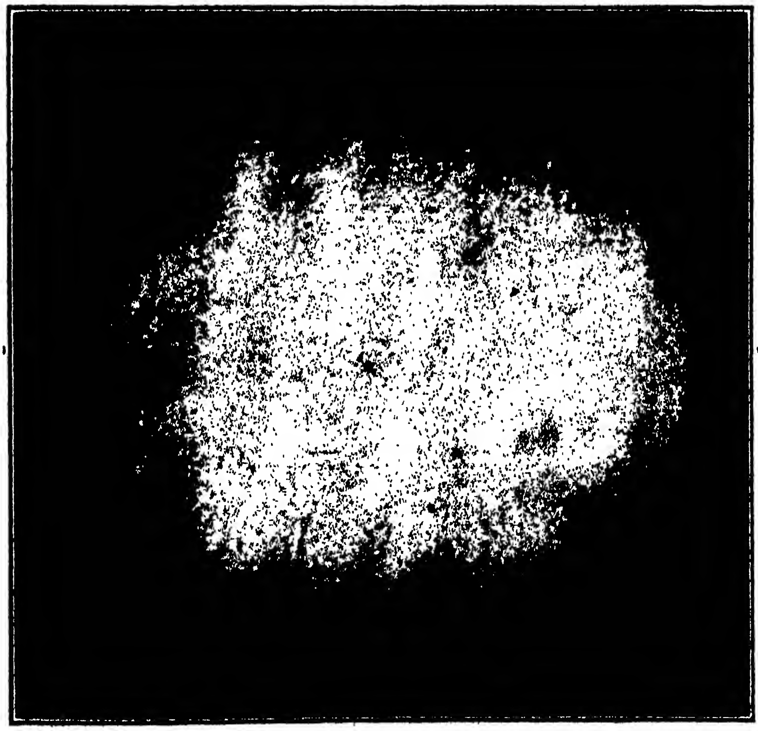


SHADOW BANDS FROM AN OLD DRAWING

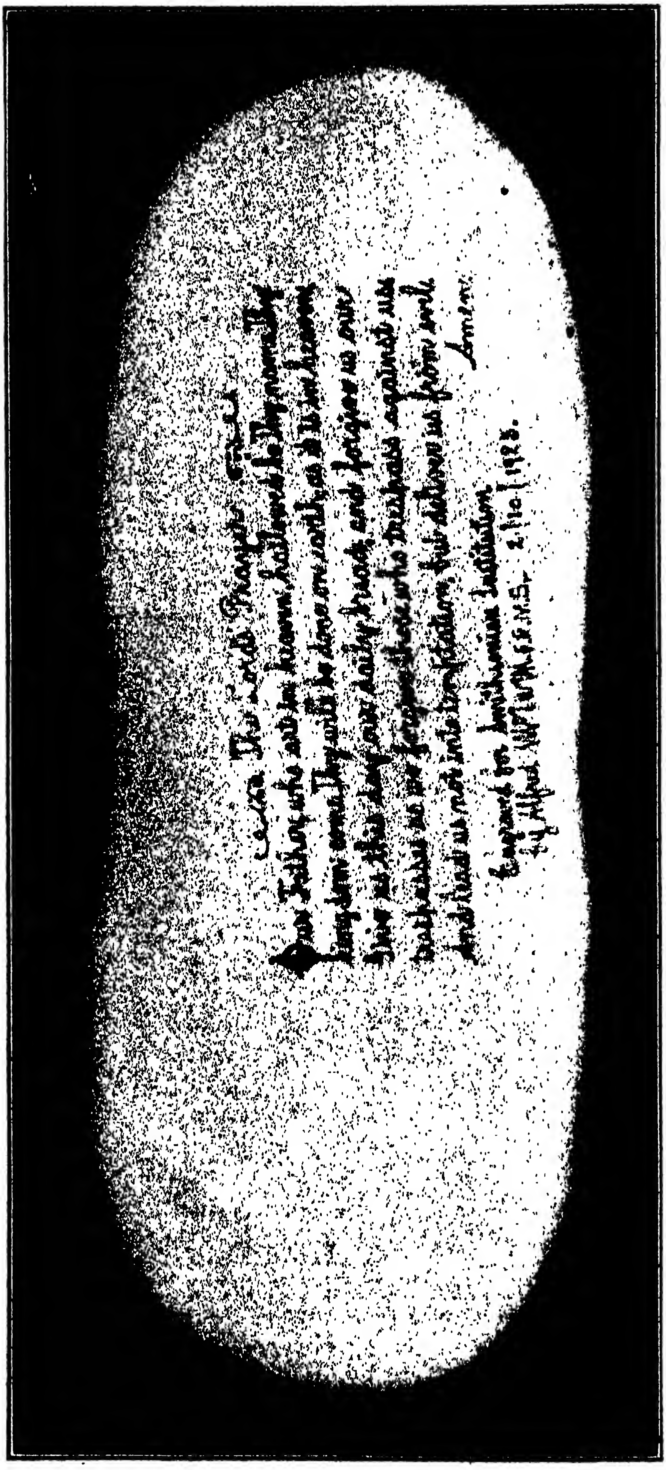
The specially designed camera is shown in an accompanying illustration and consisted essentially of a concave mirror of thirteen inches diameter and about four feet focal length. Six inches back of the focus was the film carrier just in front of which passed a focal plane shutter capable of producing extremely short exposures. The camera was kept directed to the sun and was operated by Mr. Mann from about three minutes before to about three minutes after totality. The best exposure came within about five seconds of totality and the blurred, out-of-focus images of the slender solar crescent were seen upon development to be crossed by bands of light and shade due to the atmospheric irregularities through which the narrow shaft of sunlight passed to produce the image recorded. Unquestionably these would have been lost had the exposures been made in the focus of the mirror. The extra focal method of exposure had the effect of accentuating, or one might almost say magnifying the impressions received.

The original image was sufficiently clear to allow a twofold enlargement which is shown in the reproduction. The bands appear sufficiently well defined on the negative to allow for measurements, which, when reduced, give two and a half inches for the distance between adjacent bands at the moment of the exposures, a value not inconsistent with estimates from visual observations.

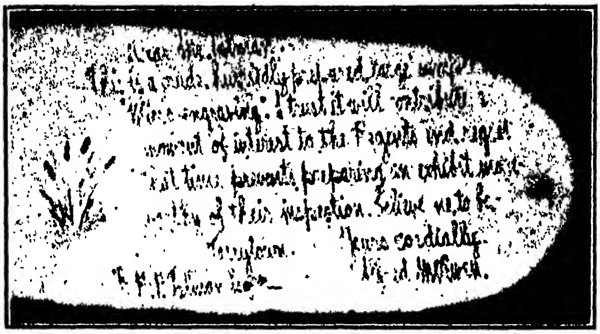
SHADOW BAND APPARATUS AS SET UP AT MIDDLETOWN, CONN., FOR THE ECLIPSE OF JANUARY 24, 1925.



SHADOW BANDS PHOTOGRAPHED AT THE ECLIPSE OF JANUARY 24, 1925, BY MEMBERS OF THE ECLIPSE PARTY FROM HARVARD UNIVERSITY, USING A SPECIAL CAMERA DEVISED BY PROFESSOR DOUGLASS, OF THE UNIVERSITY OF ARIZONA.



THE LORD'S PRAYER SEEN THROUGH THE EYE OF A NEEDLE ENLARGED ABOUT 72,000 TIMES.



MICRO-ENGRAVING

By R. P. TOLMAN
U. S. NATIONAL MUSEUM

SOME months ago the U. S. National Museum received a note of forty-six words engraved on glass, so small that it was necessary to enlarge it eighty-eight times before it could be read easily. This micro-engraved letter, which as shown above is enlarged about 70,000 times, was engraved by Alfred McEwen and was a preliminary to the permanent exhibit which has just been placed on exhibition in the Division of Graphic Arts, Smithsonian building.

The present exhibit consists of The Lord's Prayer, shown inside of the eye of a sewing needle, magnified 145 diameters. About 13,500 complete prayers of fifty-six words each could be engraved in one square inch, but this is very large compared to one measured by the Bureau of Standards, which was so small that 781,250 would have to be cut to cover one square inch; this is equivalent to 43,694,000 words. The extreme smallness of these engravings is almost incomprehensible.

The micro-engraving on exhibition was made February 10, 1925, and is very clear and distinct. It was engraved on glass, with a diamond point, by means of a micro-pantograph. The machine itself is as wonderful as the work it does. The first machine to do work of this character was invented and used by the London banker W. Peters in 1852. Fifty and sixty years ago micro-engravings were quite common, but at present they are very rare.

In time of war microscopic messages could be sent engraved on a shoe nail, on a ring or on a brass button, or an eyeglass, on almost any old thing that is smooth and hard, and they would be next to impossible to locate except by the person who knew where to look.

That it is possible for any machine to be built so accurately, without apparently any lost motion, that it is able to produce work that can only be seen under a high-power microscope and some of it is so fine that it is read only with the greatest difficulty, is almost inconceivable, but still the fact remains that it is true.

DR. ROBERT ANDREWS MILLIKAN

DIRECTOR OF THE NORMAN BRIDGE LABORATORY OF PHYSICS AND CHAIRMAN OF THE ADMINISTRATIVE COUNCIL OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY.

THE PROGRESS OF SCIENCE

"MILLIKAN" RAYS

By WATSON DAVIS, Managing Editor, Science Service

DISCOVERY of ultra-X-rays a hundred times more penetrating than ordinary X-rays were announced at the Madison meeting of the National Academy of Sciences on November 9 by Dr. R. A. Millikan, director of the Norman Bridge Laboratory of Physics of the California Institute of Technology, Pasadena, California, as the climax of twenty years of search for the cause of a mysterious radiation. Two physicists, Sir Ernest Rutherford and J. C. McClennan, noticed an unaccountable effect on their electroscopes in 1903, and the Germans tried to determine its cause by high balloon ascensions just before the world war.

Dr. Millikan's researches have extended over a decade, during which time he was assisted by I. S. Bowen, Russell Otis and Harvey Cameron.

To account for the ultra-X-rays, it is necessary to conceive that space is filled with rays of one sort or another traveling in all directions with the speed of light. This, Dr. Millikan says, is "a conception which is almost too powerful a stimulus to the imagination."

So far, Dr. Millikan has not proposed a name for the newly described radiations, though some of his colleagues have suggested calling them "Millikan rays" in his honor. He gives them a purely descriptive name, "penetrating rays." Apparently they merit the title, for according to their discoverer they will pass through six feet of solid lead before they are extinguished, whereas the "hardest" X-rays, up to the present the most penetrating radiations known, are stopped completely by half an inch of lead.

The wave-length of the "penetrating rays" is almost unimaginably short, being much less than the wave-lengths of the "hard" X-rays and of gamma rays from radium, the shortest vibrations at present familiar to physicists. The new rays fit on at the top of the known spectrum, and extend it into regions as yet unexplored. At the bottom of the spectrum are the very long waves of low-frequency alternating electric current, and in the zone above them the radio waves, with possible lengths of a mile or more. Then, with rapidly diminishing wave-lengths, come the infra-red heat rays, below the visible spectrum of light, then the light waves themselves, passing out into the ultra-violet radiations above the spectrum. In this region the wave-lengths are short enough to stagger the average person's imagination—ordinary light waves, for example, average around one fifty thousandths of an inch in length. Above the ultra violet come the still shorter waves of the X-rays and the gamma rays of radium; and above these, completing the series so far as now known, the new "penetrating rays."

Where the rays come from is an unsolved mystery. They enter the highest atmosphere from the depths of outer space, being born apparently of the disintegration of atoms or of their transmutation into other elements. Dr. Millikan states that if sufficient energy for the transmutation of elements could be generated the process would bring forth penetrating rays as a by-product. But inasmuch as the immense energy of ten

million volts or more would be necessary for this, he does not regard the prospect of human production of penetrating rays to be very promising. The concluding part of Dr. Millikan's paper follows:

HIGH FREQUENCY RAYS OF COSMIC ORIGIN

By Dr. R. A. Millikan

We chose for the first experiment Muir Lake (11,800 feet high), a beautiful body of water hundreds of feet deep just under the brow of Mount Whitney, the highest peak in the United States. Here we worked for the last ten days in August, sinking our electroscopes to various depths down to 60 feet. Our experiments brought to light altogether unambiguously a cosmic radiation of such extraordinary penetrating power that the electroscope reading kept decreasing down to a depth of 45 feet below the surface. The atmosphere above the lake was equivalent in absorbing power to 23 feet of water, so that we had found rays, coming into the earth from outer space, so penetrating that they could pass through 45 plus 23, equalling 68 feet of water or the equivalent of 6 feet of lead, before being completely absorbed. This represents rays much harder (more penetrating) than any which had before even been imagined.

The most penetrating X-rays which we produce in our hospitals can not go through half an inch of lead. Here were rays originating somewhere out in space, at least a hundred times more penetrating than these.

Further, high penetrating power means, according to modern physics, simply high frequency or short wave-length. Our experiments indicate, then, that there is a region of frequencies as far up above the X-ray frequencies as are these latter above the frequencies of light waves.

They show quite definitely, too, that these highest frequency rays are not homogeneous, but have a measurable spectral distribution, the shortest waves which we observed being a little less than twice the frequency of the longest, for the rays which we actually observed in Muir Lake changed hardness or frequency as they were filtered through greater and greater thicknesses of water, just as X-rays are successively hardened by passing through successive layers of lead. The experiments with the sounding balloons indicate that the frequencies of these cosmic rays do not extend over into the X-ray region of frequencies, else we should have obtained larger discharges in the experiments with sounding balloons when nine tenths of the atmosphere had been left beneath us.

Further, we obtained good evidence that these cosmic rays shoot through space in all directions, this evidence being found in the fact that we could observe no change whatever in their intensity throughout day or night.

All the results obtained in Muir Lake were checked with wonderful completeness by another set of observations in another snow-fed lake—Arrowhead Lake—300 miles away from Muir, 7,000 feet lower, and equally deep, where the Arrowhead Lake Development Company kindly put all their facilities at our disposal. Indeed, the absorbing power of the atmosphere between the elevations of Muir and Arrowhead lakes is the equivalent of about two meters of water, and as a matter of fact every reading in Arrowhead was practically identical with one taken in Muir at a depth two meters lower.

We can draw some fairly reliable conclusions as to the origin of these very penetrating and very high frequency rays. The most penetrating rays that we have known anything about thus far, the gamma rays of radium

and thorium, are produced only by nuclear transformations within atoms. This means that they are produced by the change of one atom over into another atom, or by the creation of a new type of atom. It is scarcely possible, then, to avoid the conclusion that these still more penetrating rays which we have here been studying are produced similarly by nuclear transformations of some sort. But these transformations must be enormously more energetic than are those taking place in any radioactive changes which we know anything about. For the frequency of any emitted ray is, according to our present knowledge, proportional to the energy of the subatomic change which gives birth to it. We can scarcely avoid the conclusion, then, that nuclear changes having an energy value perhaps fifty times as great as the energy changes involved in observed radioactive processes are taking place all through space, and that signals of these changes are being sent to us in these high frequency rays.

The energy of the nuclear change which corresponds to the formation of helium out of hydrogen is known, and from it we have computed the corresponding frequency and found it to correspond closely to the highest frequency rays which we have observed this summer. The computed frequencies of these rays also correspond closely to the energy involved in the simple capture of an electron by a positive nucleus. It is possible that this phenomenon is actually going on all through space. This is I think the most probable source of these rays. It is true that the formula underlying this computation of the frequencies of these rays from their absorption coefficients is of uncertain validity. It is a formula, nevertheless, that works well in the frequency range in which we can get independent checks upon it, namely, in that of the X-ray field and the gamma ray field.

According to this formula the wave length of the shortest waves which we have here investigated is .0004 Angstroms, or but one fiftieth of that of the hardest gamma rays heretofore known, and but one ten millionth that of ordinary light. The longest wave length which we have found is about five thirds of the shortest, or .00067 Angstroms.

When these extraordinarily high frequency rays strike the earth, according to the now well-established Compton effect, they should be transformed partially into soft scattered rays of just about the hardness, or the wave length, of the soft rays which we have actually observed on Pike's Peak and Mount Whitney. The reason these soft rays were more plentiful on the mountain peaks than at Pasadena would then be found simply in the fact that there are more than twice as many of the hard rays to be transformed at the altitudes of the peaks than at that of Pasadena. This seems to be the solution of the second of our summer's problems.

But how can nuclear transformation, such, for example, as the formation of helium out of hydrogen or the capture of an electron by a positive nucleus, be going on all through space, the resulting rays coming apparently as much from one direction as from any other, and certainly not a whit more plentifully from the direction of the sun than from that diametrically opposite to it, as evidenced by the entire equality of our midday and midnight observations? The difficulty is not so insuperable, in view of the transparency even of large amounts of matter for these hard rays, combined with Hubble's recent proof at the Mount Wilson Observatory that some of the spiral nebulae are at least a million light years away. The centers at which these nuclear changes are taking place would then only have to occur at extraordinarily widely scattered intervals to produce the intensity of the radiation observed at Muir Lake.

The only alternative hypothesis to that above presented, of high frequency rays traversing space in all directions, might seem to be to assume that the observed rays are generated in the upper layers of the atmosphere by electrons shooting through space in all directions with practically the speed of light. This hypothesis might help in interpreting the mysterious fact of the maintenance of the earth's negative charge, but it meets with insuperable obstacles, I think, in explaining quantitatively the variation with altitude of the ionization in closed vessels. In any case, this hypothesis is, in its most important aspect, very much like the one represented above, for it, too, fills space with rays of one sort or another travelling in all directions with the speed of light. From some such conception as this there now seems to be no escape. And yet it is a conception which is almost too powerful a stimulus to the imagination. Professor MacMillan, of Chicago, will wish to see in it evidence for the condensation into matter out somewhere in space of the light and heat continually being radiated into space by the sun and stars, and the psychists will be explaining all kinds of telepathic phenomena by it.

In any event, our experiments seem to point to the following conclusions: (1) That these extraordinarily penetrating rays exist; (2) that their mass absorption coefficient may be as high as .18 per meter of water; (3) that they are not homogeneous, but are distributed through a spectral region far up above X-ray frequencies—probably 1,000 times the mean frequencies of X-rays; (4) that these hard rays stimulate, upon striking matter, softer rays of about the frequency predicted by the theory of the Compton effect; (5) that these rays come into the earth with equal intensity day and night and at all hours of the day or night, and with practically the same intensity in all directions.

THE WATER-COOLED VACUUM TUBE AND TRANSATLANTIC TELEPHONY

This photograph shows Sir Joseph Thomson, the great English physicist, and Dr. F. B. Jewett, vice-president of the American Telephone and Telegraph Company and president of the Bell Telephone Laboratories, Inc., at the time of the former's visit to these laboratories. They are inspecting the 10 k. w. water-cooled vacuum tube developed by the Bell Telephone engineers. These tubes are used in the 150 k. w. radio transmitting station at Rocky Point, Long Island, at which tests undertaken for the purpose of developing commercial transatlantic telephony have been under way for the past four years. At the present time, a somewhat similar transmitting station, employing the same tubes, is under erection in England and when complete will make two-way testing and ultimately two-way telephony possible.

The transatlantic tests thus far completed constitute a very extensive survey of the effect of atmospheric conditions on the transmission of radio signals throughout all times of day and night and all seasons of the year. Before commercial transatlantic telephony is practicable, it will be necessary to supply transmitting apparatus which is so flexible in capacity as to make possible the clear transmission of the voice at all times. Furthermore, the transmitting apparatus must be so designed as to connect to the telephone land lines in both this country and Europe so that a telephone subscriber in Kansas City can converse with one in some remote part of

England as readily as though they were each located at their respective radio stations. The fundamental engineering difficulty encountered lies in the extreme variability of atmospheric conditions, the sending power required to produce a given intensity of received signal frequently increasing by 10,000 within the space of a few hours.

SIR JOSEPH THOMSON AND DR. F. B. JEWETT.

There is an old saying to the effect that success in little things leads to success in big things. The large water-cooled vacuum tube and its tiny ancestor, the telephone switchboard lamp, illustrates a case in point. Several years ago, Mr. W. G. Houskeeper, of the Bell Telephone Research Laboratories, undertook to cheapen the manufacture of switchboard lamps.

DR. HERBERT E. IVES, PRESIDENT OF THE OPTICAL SOCIETY OF AMERICA

DR. IVES TOOK AS THE TOPIC FOR HIS RETIRING PRESIDENTIAL ADDRESS "SOME PHOTOGRAPHIC PROBLEMS ENCOUNTERED IN THE TRANSMISSION OF PICTURES BY ELECTRICITY." THE PORTRAIT HERE REPRODUCED WAS TRANSMITTED OVER A LONG DISTANCE TELEPHONE LINE BY THE METHOD DESCRIBED IN THE ARTICLE BY DR. IVES IN THIS ISSUE.

For one thing, he aimed to eliminate the platinum wire which was used to bring the filament heating current through the glass wall of the lamp. Copper wire possessed one of the requirements necessary to an air-tight seal in that the molten glass adhered closely to the wire, but copper and glass, of course, have quite a different temperature coefficient of expansion, and success came only after Mr. Houskeeper found that by giving the copper wire a peculiar cross-sectional shape no cracking occurred.

His success with the very fine copper leads which he was using for switchboard lamps and the ease of making the copper seals, once the secret was learned, led him to study other and bigger types of seals between glass and copper. Some of these he brought to enormous sizes compared with seals which had previously been made. For example, in one type of vacuum tube which has been developed at the telephone laboratories, the filament heating current is over 90 amperes.

The significance of the water-cooled tube development to the radio art can scarcely be overestimated. It makes available unit tubes so large that only a very few are necessary to operate even the largest radio stations now extant with all the flexibility of action attendant upon the use of tubes.

THE PRINCIPLES OF THE TELEPHONE APPLIED TO THE PHONOGRAPH

THE engineers of the Bell Telephone Laboratories have recently made notable improvements in the phonograph art. They will be reported in an article in the December issue of the *Telephone Review,* which we are permitted to quote.

Far from being a strange place from which improvements in the phonograph might emanate, these laboratories constitute perhaps the most natural source in the world. A casual comparison might lead one to conclude that the phonograph operates mechanically while the telephone is a piece of electrical apparatus; but underlying this very superficial difference is the fact that the telephone is as much mechanical as it is electrical and that both devices are actuated by and reproduce speech sounds and the allied sounds of music. Because of this common characteristic there are similarities between the two instruments which are far more fundamental than might be guessed at first.

Adopting telephone terminology, the ordinary phonograph is a transmission line for mechanical vibrations which behaves, or rather should be made to behave, in a manner analogous to the telephone transmission line for electrical vibrations. The problems which arise in the perfecting of the phonograph transmission circuit are practically identical, from a mathematical point of view, with those met in the telephone circuit. It may be of interest to mention just a few of the analogous features. The elasticity of the phonograph needle point takes the place of a condenser, the pivoted needle arm corresponds to a transformer or repeating coil, the inertia of the needle arm to an inductance, the elasticity of the diaphragm to a condenser and the horn from which the sounds finally issue is the counterpart of a resistance. It is not surprising, therefore, that the telephone engineers should possess an insight into the problems of the phonograph which could hardly have been obtained by any other avenue than the intensive study of the telephone.

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IMPROVEMENT OF THE PHONOGRAPH

MEASURING THE "MECHANICAL IMPEDANCE" OF THE SOUND TRANSMITTING PORTIONS OF A PHONOGRAPH BY A SPECIALLY DESIGNED BRIDGE IN A MANNER ANALOGOUS TO THE BRIDGE MEASUREMENT OF ELECTRICAL IMPEDANCES.

Applying to the mechanical transmission line of the phonograph the practices which have long been standard in the electric transmission line of the telephone has resulted in an instrument which marks a great improvement over the present phonograph in all respects. The sound of the voice and all music is far more natural; the volume of sound can be much increased without unpleasant "blasting" due to resonance; and wear on records is much reduced.

So far as its outward construction is concerned, the new phonograph appears very similar to the old. To the critical eye its interior differs, however, in many fundamental respects, especially in the construction of the diaphragm, the needle arm and the horn. This horn, although several feet in length, is folded back and forth on itself so as to be easily contained in cabinets about the size of the present phonograph cabinets.

Cutting of records has also come in for an improvement corresponding to that in the reproducing instrument. This has been made possible by the perfecting of vacuum tube amplifiers, so that the energy used in driving the cutting tool through the master record is not derived entirely from the sound waves, but is largely supplied by an electromagnetic device connected to the output of the amplifier.

The Western Electric Company has recently consummated contracts through which these improvements in recording, as well as in phonograph instruments, are now to become available to the public.

EVOLUTION, THE COURT AND THE CHURCH

JUDGE JOHN T. RAULSTON, who presided at the Scopes evolution trial at Dayton, Tenn., urged in New York City on November 8 that the state prohibit the teaching of evolution in her schools in order to prevent corruption of society and the downfall of civilization. Speaking before an audience in Calvary Baptist Church, where he was introduced by the pastor, the Rev. John Roach Stratton, he defined this conception of evolution and declared that as judge it had been his duty to combat it in order to "uphold the integrity of the Bible."

According to the report in the *Times*, the judge told first of his own mountain upbringing, which included daily instruction in the Bible. "My father and mother tried to teach us to believe in Jesus Christ," he said, "and we thought that was good enough. We of Tennessee esteem science, we love knowledge. But we know that true science is consistent with Christ and with his religion, because God made both. If science is not consistent with Christ's religion, with all due reverence to science, we will take our choice as to which we will keep."

It was for this reason, he said, that the legislature of Tennessee had a "perfect right" to declare the teaching of evolution against the law. He paid tribute to William Jennings Bryan and to the other lawyers of the prosecution. Then he denounced Clarence Darrow, of the defense, and pictured him as cringing for mercy before the Court, "when I might have sent him to jail for contempt." Bryan's conduct at this juncture, he said, "illustrated the comparison between the Christian and the un-Christian. Bryan," he said, "slipped over to my desk, and, laying his hand on my arm, said, 'Judge, be merciful.' "

"The counsel for the defense," he went on, "brought learned scientists from this City of New York and from many other cities to enlighten the court on what the Tennessee statute meant when it said that it was against the law to teach evolution to our little ones. The meaning of the statute was not ambiguous; it was perfectly clear to the court. That is why I did not admit their evidence.'

Judge Raulston condemned evolution as "only a theory, a hypothesis, a guess," and quoted Darwin and others to the effect that evolution had "robbed them of their hope of resurrection."

Depicting his idea of the origin of evolution, he said: "A couple of scientists wandered down to the seashore one day and found some old bones and fossils. This proved to them that all life is a result of a little accident that happened millions of years ago in the bottom of the ocean. Some atoms of carbon and hydrogen and oxygen got together down there and suddenly there was a little thing that swam around.

"Pretty soon it got a little bigger and crawled out on shore. It had two freckles on it, and those were eyes, and if it had had a hundred freckles I wonder if you and I would have a hundred eyes. Well, it had two warts on its underneath, and if it had had a hundred warts I wonder if we would all be like centipedes.

"An evolutionist comes to me and says he has a proposition, and I ask him what he can give me. He says he can give me these bones and fossils, but that I must abandon my belief in Genesis, my belief in the immaculate conception and the Virgin birth, my belief in the prophets and in Revelation.

"And I answer him back, 'Take your doctrine that teaches that my ancestors were monkeys and apes, and stick it in that hot place the Scripture tells us of!' "

DR. ALEŠ HRDLIČKA,

CURATOR OF THE DIVISION OF PHYSICAL ANTHROPOLOGY OF THE U. S. NATIONAL MUSEUM. DR. HRDLIČKA HAS JUST RETURNED TO WASHINGTON FROM AN EXPEDITION TO AUSTRALIA, INDIA, CEYLON, JAVA AND SOUTH AFRICA IN THE INTEREST OF RESEARCHES ON MAN'S ANTIQUITY AND EVOLUTION.

Judge Raulston further denounced evolution on the ground that it was an incentive to larceny and murder. "If I listen to evolution and lose my faith in Genesis," he said, "I am afraid I'll lose faith in the rest of the Bible; and if I want to commit larceny I'll say I don't believe in the part of the Bible that says 'Thou shalt not steal.' Then I'll go out and steal." The same thing might happen, he said, if he wanted to commit murder.

Judge Raulston concluded with a second denunciation of those who accuse some Tennesseans of being yokels. "In behalf of my home state," he said, "I want to tell you that the charge that we are yokels and ignoramuses is not justified. No man is justified in calling us that. They have no right to charge my people with being ignoramuses. But I will say that if more learning will cause us to lose our faith in the deity of Christ and our hope in resurrection, then I pray to God to leave us in our state of ignorance."

THE KANSAS CITY MEETING OF THE AMERICAN ASSOCIATION

THE eighty-second meeting of the American Association for the Advancement of Science will be held at Kansas City from December 28, 1925, to January 2, 1926, under the presidency of Dr. Michael I. Pupin, of Columbia University. Annual meetings so far west as this are of infre-

DR. EPHRAIM PORTER FELT,

NEW YORK STATE ENTOMOLOGIST, WHO RECENTLY COMPLETED THIRTY YEARS OF SERVICE. AN ARTICLE BY DR. FELT ON "INSECTS AND HUMAN WELFARE" APPEARS IN THE PRESENT NUMBER OF THE MONTHLY.

quent occurrence and this is the first to be held in Kansas City. This year brings the great scientific convention to a region characterized by typical American progress and prosperity, to a community of high intellectual and educational ideals, and many members and other friends of the association who dwell in the region now to be visited and who do not generally find it possible to attend the annual meetings, will be able this year to receive the benefits of attending. The distance to be traveled will be relatively short from places in the Mississippi and Missouri valleys, and the facilities for transportation to Kansas City from all parts of the country are unsurpassed.

The hotel accommodations at Kansas City are excellent. The larger hotels are conveniently grouped in a small area and the Kansas City Junior College, at which many of the sessions will be held, is situated but a short distance away. The local arrangements for the meeting are in the hands of an able local committee, of which Dr. A. Ross Hill is chairman. The Convention Bureau of the Kansas City Chamber of Commerce, which is deeply appreciative of the aims of men and women of science, is giving very valuable aid to the local committee.

The preliminary announcement of the meeting appears in *Science* for November 27, a complimentary copy of which has been sent to each subscriber for THE SCIENTIFIC MONTHLY. A list of Kansas City hotels was published in *Science* for November 14, and additional announcements are to be made in *Science* from week to week. The general program of the meeting, which will be available at the registration room in Kansas City on the morning of Monday, December 28, will contain full information.

All branches of science will be well represented in the sessions of the association and of the numerous associated societies that will take part in the convention. A series of important general sessions will be devoted to lectures by prominent scientific men on the general aspects of their fields of study and another series of illustrated popular lectures, also by leading scientists, will bring the benefits of the meeting to those who are not engaged in scientific work.

The address of the retiring president of the association, Dr. J. McKeen Cattell, president of The Psychological Corporation and editor of *Science* and THE SCIENTIFIC MONTHLY, will be given on Monday evening, on "Some Psychological Experiments." The annual Sigma Xi lecture, under the joint auspices of the association and the Society of Sigma Xi, will be given on Tuesday evening by President F. D. Farrell, of the Kansas State Agricultural College, on "The Desert becomes a Garden." Dr. Dayton C. Miller, of the Case School of Applied Science, president of the American Physical Society, will give his presidential address on Tuesday afternoon on "Ether Drift Experiments at Mt. Wilson." The annual Josiah Willard Gibbs lecture, under the joint auspices of the association and the American Mathematical Society, will be given on Wednesday afternoon by Professor James Pierpont, of Yale University, on "Some Modern Views of Space." A program of general interest on the rôle of science in education is planned also for Wednesday afternoon. The Wednesday evening program will be devoted to a discussion of the general relations of engineering to the fundamental sciences, at which President Pupin will preside. On Thursday evening Dr. F. R. Moulton, of the University of Chicago, will speak on "The Origin and Evolution of Worlds." Several other speakers for general sessions remain to be announced.

One of the features for which the Kansas City meeting may be specially remembered will be the science exhibition, which is being planned on a much more elaborate scale than has ever been attempted before by the association. Individual scientists and research laboratories and institutions are to exhibit research apparatus, methods and results, manufacturers and distributors of scientific apparatus are to display their recent specialties and publishers of scientific books are to show their newest volumes. The exhibition is to be held in the Alladin Hotel, which has just been completed. Ample and convenient space has been provided. The director of the exhibition is Major H. S. Kimberly, who is to be addressed at the Washington office of the association, in the Smithsonian Institution Building.

BURTON E. LIVINGSTON,
Permanent Secretary

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